(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 1 956 101 A1**

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 158(3) EPC

(43) Date of publication:
13.08.2008 Bulletin 2008/33

(21) Application number: **06822967.3**

(22) Date of filing: **27.10.2006**

(51) Int Cl.:
C22B 1/20 $^{(2006.01)}$ ***F27B 21/08*** $^{(2006.01)}$

(86) International application number:
PCT/JP2006/322049

(87) International publication number:
WO 2007/052776 (10.05.2007 Gazette 2007/19)

(84) Designated Contracting States:
DE FR GB

(30) Priority: **31.10.2005 JP 2005317470**
31.03.2006 JP 2006096693
15.09.2006 JP 2006250280

(71) Applicant: **JFE Steel Corporation**
Tokyo, 100-0011 (JP)

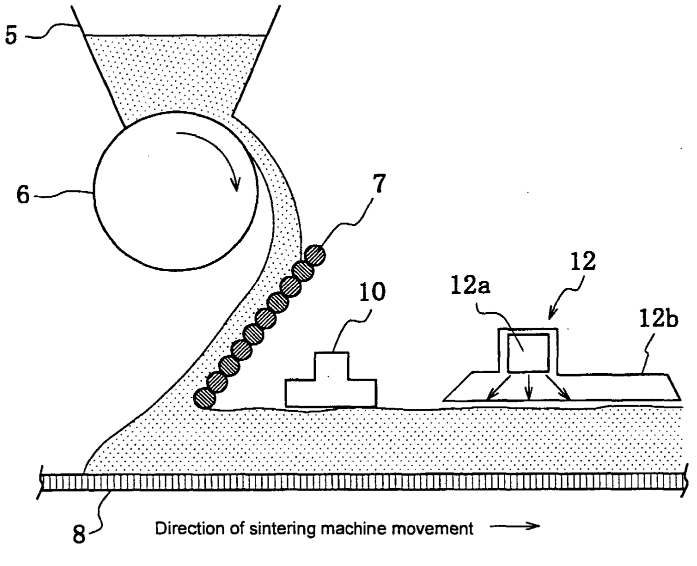
(72) Inventors:
- **OYAMA, Nobuyuki,**
  c/o Intellectual Property Dept.
  Tokyo 100-0011 (JP)
- **SATO, Hideaki,**
  c/o Intellectual Property Dept
  Tokyo 100-0011 (JP)
- **MACHIDA, Satoshi,**
  c/o Intellectual Property Dept.
  Tokyo 100-0011 (JP)
- **TAKEDA, Kanji,**
  c/o Intellectual Property Dept.
  Tokyo 100-0011 (JP)

(74) Representative: **HOFFMANN EITLE**
Patent- und Rechtsanwälte
Arabellastrasse 4
81925 München (DE)

(54) PROCESS FOR PRODUCING SINTERED ORE AND SINTERING MACHINE

(57) Provided is the method for producing sintered ore by feeding varieties of gaseous fuels from above the sintering bed of sintering raw material which is charged on the pallet of the sintering machine. The gaseous fuel fed from above the sintering bed on the pallet is a gaseous fuel which is diluted to below the lower limit concentration of combustion. On feeding the gaseous fuel to conduct sintering operation, at least one of a feed position, an ultimate maximum temperature in the sintering bed, and a holding time in high temperature zone is adjusted. Also provided is the sintering machine having the gaseous fuel feed apparatus.

FIG. 5



Printed by Jouve, 75001 PARIS (FR)

Description

Field of the Invention

[0001] The present invention relates to a method for producing sintered ore as a raw material for blast furnace using a downward suction type Dwight Lloyd (DL) sintering machine, and to a sintering machine applied to the method.

Description of Related Arts

[0002] Sintered ore which is the main raw material of the blast furnace iron making process is manufactured generally by the process illustrated in FIG. 1. The raw materials include fine iron ore, recovered fine in iron works, under-sieve fine of sintered ore, CaO-containing raw material such as limestone and dolomite, agglomeration assistant such as burnt lime, coke fine, and anthracite. The CaO-containing raw material such as limestone and dolomite is hereinafter referred to as the "CaO-based auxiliary raw material". These raw materials are supplied from the respective hoppers 1 onto a conveyer at the respectively specified rates. The supplied raw materials are blended together and agglomerated in a drum mixer 2 or the like with the addition of adequate amount of water, thus forming a sintering raw material which is quasi-particles having a mean particle size between 3.0 and 6.0 mm. Thus formed sintering raw material is dried in a rotary kiln 3. The dried sintering raw material is charged onto an endless traveling moving pallet 8 of the sintering machine from surge hoppers 4 and 5 located above the sintering machine via a drum feeder 6 and a charge chute 7, thereby forming a charged bed 9 which is also called the sintering bed. The thickness (height) of the sintering bed is approximately in a range from 400 to 800 mm. Then, the carbonaceous material in the sintering bed is ignited by an ignition furnace 10 positioned above the sintering bed 9. By the downward suction of air using wind boxes 11 located below the pallet 8, the carbonaceous material in the sintering bed successively combusts downward. The generated combustion heat brings the sintering raw material combust to melt, thus forming a sintered cake. After that, the sintered cake is crushed and regulated in size, thereby being collected as the product sintered ore composed of 5.0 mm or coarse agglomerates.

[0003] According to the above producing process, first the ignition furnace 10 ignites the surface of the sintering bed. The carbonaceous material in the sintering bed is combusted by the suction gas sucked from the top of the sintering bed down to the lower layer portion thereof, and the combustion propagates to downward layer and front side with the travel of the pallet 8. With the progress of combustion, water content in the sintering raw material particles in the sintering bed is vaporized by the heat generated from the combustion of carbonaceous material, which vapor and water are then sucked downward, thus the water is enriched in the sintering raw material in a wet zone in lower layer where the temperature is not increased yet. When the water concentration increases to some extent, the voids among the raw material particles, which voids are the passage of the suction gas, are filled with the water, thus increasing the gas flow resistance. Also the melted portion which is necessary for the sintering reaction increases the gas flow resistance.

[0004] The production of sintered ore, (t/hr), is generally determined by [the productivity of sinter (t/hr•m^2) x the area of sintering machine (m^2)]. The production varies with the width and length of the sintering machine, the thickness of the raw material packed bed (the thickness of sintering bed), the bulk density of sintering raw material, the sintering (combustion) time, the yield, and other variables. To increase the production of the sintered ore, there are expectedly effective methods such as the one to improve the gas permeability (pressure loss) of the sintering bed to shorten the sintering time, and the one to improve the cold strength of the sintered cake before crushing to improve the yield.

[0005] FIG. 2 is a graph showing the pressure loss and the temperature distribution in the sintering bed. The temperature distribution curve in FIG. 2 shows that the moving combustion (flame) front comes at about 400 mm above the pallet in the sintering bed in the thickness direction thereof. The pressure loss distribution at that moment is about 60% in the wet zone and about 40% in the combustion and melting zone.

[0006] FIG. 3 shows the temperature distribution in the sintering bed at high productivity of sintered ore and at low productivity thereof, respectively. The holding time in high temperature zone where the temperature is kept at or above 1200°C of beginning the melt of raw material particles is expressed by t_1 for the case of low productivity and by t_2 for the case of high productivity which emphasizes the productivity. For the case of high productivity, the pallet moving speed has to be increased, thus the holding time t_2 in high temperature zone becomes short compared with the holding time t_1 in high temperature zone for low productivity. Since the time kept at high temperature becomes short, sintering becomes insufficient, and the cold strength of sintered ore decreases, thus deteriorating the yield. Consequently, for improving the production of high strength sintered ore, it should be effective to increase the strength of sintered ore, or the cold strength of the sintered ore, by some method, thus to maintain and improve the yield. The cold strength of sintered ore is represented by shutter index (SI) and tumbler index (TI).

[0007] FIG. 4(a) illustrates the principle of the progress of sintering in the sintering bed on the pallet of sintering machine, FIG. 4 (b) shows the temperature distribution (heat pattern) in the sintering process in the sintering bed, and FIG. 4 (c) shows the yield distribution of the sintered cake. As shown in FIG. 4(b), the upper portion of the sintering bed, is difficult to increase the temperature compared with the lower layer portion thereof, thus the holding time in high temperature zone becomes short. As a result, the combustion and melting reaction (sintering reaction) becomes insufficient at upper portion of the sintering bed, and as shown in FIG. 4(c), the strength of the sintered cake decreases to suppress the increase in the yield, thereby likely deteriorating the productivity.

[0008] There are proposed methods to assure high temperature holding at upper portion of the sintering bed.

[0009] JP-A-48-18102, (the term "JP-A" referred to herein signifies "Unexamined Japanese Patent Publication"), discloses the injection of a high concentration flammable gas directly after the ignition furnace. Since the amount of carbonaceous material is not decreased on injecting the flammable gas, the sintering layer becomes a high temperature of exceeding 1380°C, which fails to fully improve the cold strength and to attain improvement in the yield. The injection of flammable gas directly after the ignition furnace for a period of 0 to 2 minutes has a possibility of igniting the flammable gas to raise serious fire accident, thus the technology is not realistic, and has not been practically applied.

[0010] JP-A-55-18585 discloses, for attaining high temperature in the sintering bed of the sintering raw material, the installation of a hood above the sintering bed, and injection of a mixed gas of air and coke oven gas through the hood at a position directly after the ignition furnace. The temperature in the sintering layer becomes as high as above 1350°C, which fails to attain the effect of the injection, and has a possibility of ignition of the mixed flammable gas to lead to serious fire accident. Therefore, the technology is not brought into practical application.

[0011] JP-A-5-311257 discloses a method of injecting a low-melting point flux, carbonaceous material, and flammable gas, at a time, at directly after the ignition furnace. Since the method also injects the flammable gas in a state that flame remains on the surface, the method has high possibility of inducing serious fire accident, and since the thickness of the sintering zone is not fully increased, (about 15 mm or less), the effect cannot fully be attained. In addition, since a large amount of low melting point flux exists, excessive melting phenomenon occurs at upper layer portion, and the pores as the air flow passage are plugged, which deteriorates the gas permeability to decrease the productivity. Consequently, the technology is also not practically applied at present.

[0012] As described above, the conventional technologies are not brought into practical use. Accordingly, there is wanted to search for the injection conditions with satisfactory economy.

[0013] An important variable in the quality adjustment of sintered ore is the adjustment of ultimate maximum temperature during combustion and of holding time in high temperature zone. The quality of sintered ore is determined by the adjustment of them. To this point, the method described in JP-A-48-18102 is a technology to increase the temperature at upper portion of the sintering bed in the first half period of the sintering process by bringing a gaseous fuel combust on the surface of the sintering bed. The method, however, uses high concentration of gaseous fuel, which may lack the quantity of air (oxygen) supporting the combustion of the gaseous fuel, thereby deteriorating the combustion of the carbonaceous material (coke) of the sintering raw material in some cases, thus raising a problem of failing to improve the quality of sintered ore. The method described in JP-A-55-18585 is a method to attain further high temperature by feeding a flammable gas together with the combustion air utilizing a hood. The method also lacks the heat. That is, the method also consumes oxygen, necessary for the combustion of coke, in the combustion of the injected flammable gas in the high temperature zone, which raises a problem of delayed combustion of coke and of elongation of sintering period.

[0014] The method described in JP-A-5-311257 increases the quantity of air (oxygen), and mixes a low melting point flux and a carbonaceous material. Accordingly, although the combustion rate of flammable gas and coke increases, the simultaneous injection of the low melting point flux and the powder raises a problem of decreasing the permeability of combustion air.

SUMMARY OF THE INVENTION

[0015] It is an object of the present invention to provide a method for producing high strength sintered ore at high yield in the operation of a downward suction type sintering machine without deteriorating the gas permeability in entire sintering bed, and to provide a sintering machine used for the method.

[0016] To achieve the object, the present invention provides a method for producing sintered ore, comprising the steps of:

a charging step of charging a sintering raw material containing a fine iron ore and a carbonaceous material onto a pallet moving in circulation, thus forming a sintering bed containing the carbonaceous material on the pallet;
an igniting step of igniting the carbonaceous material on the surface of the sintering bed at an ignition furnace;
a sintering step of combusting the carbonaceous material in the sintering bed by sucking air through a wind box positioned below the pallet, thus forming a sintered cake utilizing the generated combustion heat; and
a gaseous fuel combusting step of feeding a gaseous fuel which is diluted to below the lower limit concentration of combustion in the sintering bed from above the sintering bed, and combusting the gaseous fuel in the sintering bed.

[0017] The gaseous fuel combusting step preferably comprises:

feeding a gaseous fuel which is diluted to below the lower limit concentration of combustion in the sintering bed from above the sintering bed, and combusting the gaseous fuel in the sintering bed; and
adjusting an ultimate maximum temperature in the sintering bed or a holding time in high temperature zone in the sintering bed, or an ultimate maximum temperature in the sintering bed and a holding time in high temperature zone in the sintering bed.

[0018] The ultimate maximum temperature in the sintering bed is preferably adjusted by the following modes.

(A) The gaseous fuel diluted to below the lower limit concentration of combustion is fed from above the sintering bed, thereby adjusting the ultimate maximum temperature in the sintering bed.
(B) The gaseous fuel diluted to below the lower limit concentration of combustion is fed from above the sintering bed, and the amount of the carbonaceous material in the sintering raw material is adjusted, thereby adjusting the ultimate maximum temperature in the sintering bed.
(C) The gaseous fuel diluted to below the lower limit concentration of combustion is fed from above the sintering bed, and the feed amount of the gaseous fuel is adjusted, thereby adjusting the ultimate maximum temperature.
(D) The gaseous fuel diluted to below the lower limit concentration of combustion is fed from above the sintering bed, and the amount of the carbonaceous material in the sintering raw material and the feed amount of the gaseous fuel are adjusted, thereby adjusting the ultimate maximum temperature.

[0019] As of above (A) through (D), the ultimate maximum temperature is preferably adjusted to a range from 1205°C to 1350°C.
[0020] The holding time in high temperature zone in the sintering bed is preferably adjusted by the following modes.

(a) The gaseous fuel diluted to below the lower limit concentration of combustion is fed from above the sintering bed, thereby adjusting the holding time in high temperature zone in the sintering bed.
(b) The gaseous fuel diluted to below the lower limit concentration of combustion is fed from above the sintering bed, and the concentration of the gaseous fuel is adjusted responding to the amount of the carbonaceous material in the sintering raw material, thereby adjusting the holding time in high temperature zone in the sintering bed.

[0021] The gaseous fuel combusting step preferably comprises adjusting a shape of the combustion and melting zone in the following modes.

(A) The gaseous fuel diluted to below the lower limit concentration of combustion is fed from above the sintering bed, thereby adjusting the shape of the combustion and melting zone.
(B) The gaseous fuel diluted to below the lower limit concentration of combustion is fed from above the sintering bed, and the holding time in high temperature zone of the combustion and melting zone is extended, thereby adjusting the cold strength of the sintered ore.
(C) The gaseous fuel diluted to below the lower limit concentration of combustion is fed from above the sintering bed so as at least a portion thereof to be left unburned until reaching the combustion and melting zone in the sintering bed, thereby adjusting the shape of the combustion and melting zone. It is more preferable to adjust the thickness in the height direction of the combustion and melting zone and/or to adjust the width in the pallet moving direction.

[0022] Furthermore, it is preferable that the gaseous fuel combusting step is conducted in the following modes in relation to the feed position of the gaseous fuel.

(a) The gaseous fuel diluted to below the lower limit concentration of combustion is fed from above the sintering bed, and the gaseous fuel is combusted in the sintering bed, and further the feed position of the gaseous fuel to the sintering bed is adjusted.
(b) The gaseous fuel diluted to below the lower limit concentration of combustion is fed from above the sintering bed at a position after the ignition furnace, thereby combusting the gaseous fuel in the sintering bed.
(c) The gaseous fuel diluted to below the lower limit concentration of combustion is fed in a region of 15 mm or larger thickness of the combustion and melting zone, thereby combusting the gaseous fuel in the sintering bed.
(d) The gaseous fuel diluted to below the lower limit concentration of combustion is fed at a position that the combustion front reaches 100 mm or deeper under the surface layer, thereby combusting the gaseous fuel in the sintering bed. It is more preferable to feed the gaseous fuel having a concentration below the lower limit of combustion at or after the position that the combustion front reaches 200 mm below the surface layer.
(e) The gaseous fuel diluted to below the lower limit concentration of combustion is fed near both side walls of the sintering bed, thereby combusting the gaseous fuel in the sintering bed.

(f) The gaseous fuel diluted to below the lower limit concentration of combustion is fed from above the sintering bed in the longitudinal direction of the sintering machine, thereby combusting the gaseous fuel in the sintering bed, thus adjusting the cold strength of the sintered ore.

[0023] The gaseous fuel is preferably a flammable gas which is diluted to 75% or less and 2% or more of the lower limit concentration of combustion, and more preferably a flammable gas diluted to 60% or less and 2% or more of the lower limit concentration of combustion, and most preferably a flammable gas diluted to 25% or less and 2% or more of the lower limit concentration of combustion.

[0024] The gaseous fuel is preferably at least a gas selected from the group consisting of blast furnace gas, coke oven gas, a mixed gas of blast furnace gas and coke oven gas, propane gas, natural gas, and methane gas.

[0025] Furthermore, the present invention provides a sintering machine comprising pallets moving in circulation, suction wind boxes installed below the pallet, a raw material charge apparatus for charging the sintering raw material onto the pallet, and an ignition furnace for igniting the carbonaceous material in the sintering raw material, characterized in that a gaseous fuel feed apparatus is installed at downstream side of the ignition furnace to inject the gaseous fuel diluted to below the lower limit concentration of combustion into the sintering bed from above thereof.

[0026] The gaseous fuel feed apparatus is preferably installed at least one unit thereof at downstream side of the ignition furnace in the longitudinal direction of the sintering machine.

[0027] The gaseous fuel feed apparatus is more preferably located at a position between the stage that the combustion front propagates below the surface layer in the pallet moving direction and the stage of completion of the sintering.

[0028] The gaseous fuel feed apparatus is preferably installed near the side wall.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029]

FIG. 1 illustrates the sintering process.

FIG. 2 is a graph showing the pressure loss and the temperature distribution in the sintering layer.

FIG. 3 is a graph showing the temperature distribution at high productivity and at low productivity.

FIG. 4 is a graph showing the temperature distribution and the yield distribution in the sintering machine.

FIG. 5 illustrates the gaseous fuel injection process according to the present invention.

FIG. 6 shows figures (photographs) illustrating the transition of the combustion and melting zone in a test pot, indicating an experimental result according to the method of the present invention.

FIG. 7 is comparison graphs for the results of sintering pot tests.

FIG. 8 is a graph illustrating the calculation procedure of the combustion limit of gaseous fuel.

FIG. 9 illustrates the temperature dependency of combustion.

FIG. 10 illustrates the influence of the kind of gas on injecting the gaseous fuel.

FIG. 11 illustrates the relation of the injection gas concentration, the shutter strength, the yield, the sintering time, and the productivity.

FIG. 12 is a schematic diagram of the sintering reaction.

FIG. 13 is a schematic graph of the formation process of skeleton crystalline secondary hematite.

FIG. 14 shows the observed Figures (photographs) of the combustion limit on injecting a diluted propane.

FIG. 15 shows the effect of the injection position.

FIG. 16 shows the effect of the injection position.

FIG. 17 illustrates the intralayer temperature distribution during sintering.

FIG. 18 illustrates the result of investigation of the effect of injection position.

FIG. 19 shows the graphs giving the changes with time of the temperature (a) of the sintering bed on injecting a diluted propane, the flue gas temperature (b), the gas flow rate (c), and the flue gas composition (d).

FIG. 20 shows the graphs giving the changes with time of the temperature, (a) and (a'), of the sintering bed on injecting a diluted propane and on injecting the gas with solely increased coke amount, respectively, the flue gas temperature (b) and (b'), respectively.

FIG. 21 shows the graphs giving the result of test for the sintering characteristics under various injection conditions.

FIG. 22 shows the comparison graphs giving the changes in the mineral composition under various injection conditions.

FIG. 23 is a graph showing the changes in apparent specific gravity of product sintered ores.

FIG. 24 is a graph showing the distribution of pores not larger than 0.5 mm in size in the product sintered ores.

FIG. 25 is the schematic drawings of sintering behavior during the use of sole coke (a) and during the gas injection (b).

FIG. 26 is the schematic drawing of pore structure on injecting a diluted gas.

FIG. 27 shows graphs of experimental result on the limit coke ratio that can keep the cold strength.

FIG. 28 shows the figures (photographs) indicating the result of Example 1.
FIG. 29 shows the figures (photographs) indicating the result of Example 2.

[0030] The reference symbols used in above FIG. 1 to 29 are the following.

1: Raw material hopper
2: Drum mixer
3: Rotary kiln
4, 5: Surge hopper
6: Drum feeder
7: Charge chute
8: Pallet
9: Sintering bed
10: Ignition furnace
11: Wind box
12: Gaseous fuel feed apparatus

EMBODIMENTS OF THE INVENTION

[0031] The method for producing sintered ore according to the present invention comprises the steps of charging, igniting, sintering, and gaseous fuel combusting. The charging step charges the sintering raw material containing a fine iron ore and a carbonaceous material onto the pallets moving in circulation, thereby forming the sintering bed containing the carbonaceous material on the pallet. The igniting step ignites the carbonaceous material on the surface of the sintering bed at the ignition furnace. The sinter step sucks air via the wind boxes located under the pallet to combust the carbonaceous material in the sintering bed, and forms the sintered cake utilizing the generated combustion heat. The gaseous fuel combustion step feeds the gaseous fuel diluted to below the lower limit concentration of combustion from above the sintering bed, thereby combusting the gaseous fuel in the sintering bed. The gaseous fuel combustion step is a feature of the present invention.

[0032] In the gaseous fuel combustion step, it is preferable to use a flammable gas, as the gaseous fuel, which dilutes the firing component to 75% or less of the lower limit concentration of combustion in air at normal temperature, more preferably to 60% or less, and most preferably that diluted to 25% or less. There are two reasons that the flammable gas diluted to 75% or less of the lower limit concentration of combustion is preferred.

(a) Since the feed of the gaseous fuel to upper portion of the sintering bed may induce explosive combustion in some cases, the condition establishes the state of not combusting even with an ignition source at least at normal temperature.

(b) The operation is given in a state that, even if the gaseous fuel reaches the electric precipitator and the like at downstream side of the sintering machine without completely combusted on the sintering machine (in the sintering bed), the combustion never occurs under electric discharge of the electric precipitator, or under the condition of below the lower limit concentration of combustion.

[0033] As described later, the concentration of the gaseous fuel has to be diluted so as to avoid lack of air (oxygen) necessary for the combustion of the entire carbonaceous material (solid fuel + gaseous fuel) in the sintering raw material, thus to avoid insufficient combustion. The gaseous fuel is preferably a flammable gas diluted to 2% or more of the lower limit concentration of combustion. If the concentration is 2% or more, the strength and the yield of sintered ore are further improved. The gaseous fuel is adjusted in terms of concentration depending on the amount of carbonaceous material (solid fuel). Furthermore, as described later, the gaseous fuel can adjust the combustion at a specified position in the region in the sintering bed by diluting the gaseous fuel.

[0034] According to the method for producing sintered ore of the present invention, the diluted gaseous fuel is fed to the sintering bed after igniting the carbonaceous material in the sintering bed. At the position immediately after the ignition, even if the diluted gaseous fuel is fed, combustion occurs only on the surface layer, and the sintering layer is not affected. It is preferable that the feed of the diluted gaseous fuel to the sintering bed is done after firing the sintering raw material in the upper portion of the sintering bed and after forming the sintered cake layer. The feed of the diluted gaseous fuel can be done at an arbitrary position if only the sintered cake layer is formed. The reasons of feeding the diluted gaseous fuel after forming the sintered cake are the following.

(a) If the gaseous fuel is fed in a state that the sintered cake is not formed yet at upper portion of the sintering bed, an explosive combustion may occur on the sintering bed.

(b) The feed of the gaseous fuel places the target at a portion that the yield increase is required. That is, it is effective to feed the gaseous fuel to a portion to be increased in the strength of sintered ore.

[0035] To adjust either of the ultimate maximum temperature or the holding time in high temperature zone in the sintering bed, it is preferable to feed the diluted gaseous fuel under the condition of the thickness of the combustion and melting zone at least 15 mm or more, more preferably 20 mm or more, and most preferably 30 mm or more. If the thickness thereof is less than 15 mm, owing to the cooling by air (a mixed gas of air and gaseous fuel) sucked through the sintered layer (sintered cake), the feed of gaseous fuel does not accompany the increase in the thickness of combustion and melting zone, which results in insufficient effect of the gaseous fuel feed. When the gaseous fuel is diluted and is fed in a stage of 15 mm or larger thickness of the combustion and melting zone, preferably 20 mm or more, and more preferably 30 mm or more, the thickness of the combustion and melting zone significantly increases, thus increasing the holding time in high temperature zone.

[0036] The confirmation of thickness of the combustion and melting zone can be given by, for example, using a transparent quartz window or a vertical tubular test pot. The confirmation contributes to the determination of charge position of the diluted as fuel.

[0037] The diluted gaseous fuel is preferably fed at a position where the combustion front propagates below the surface layer, and at a position where the combustion and melting zone becomes deep by 100 mm or more, more preferably 200 mm or more, from the surface layer. That is, the feed of the diluted gaseous fuel is preferably given targeting the intermediate to low layer regions. For instance, the diluted gaseous fuel is fed so as to begin the combustion at a stage of intermediate to low layer portions in the sintering bed after forming the sintered cake in the sintering bed, or at the stage that the combustion front propagates to 100 mm depth from the surface layer, (so as the diluted gaseous fuel to reach the region in unburned state). The reason is that, at the position of 100 mm or more of depth, the effect of cooling by air sucked through the sintered layer becomes weak, and the increase in the thickness of the combustion and melting layer is induced. More preferably, a depth of 200 mm or more eliminates the effect of cooling by air, and the thickness of the combustion and melting layer increases to 30 mm or more. The feed is more preferably done at both ends in the width direction (the direction perpendicular to the pallet moving direction) near the side wall where the deterioration of yield is significant.

[0038] A preferable positioning of the gaseous fuel feed apparatus varies with the scale of the sintering machine. For example, at a scale of the sintering machine of 90 m of length, and at a gaseous fuel feed capacity from 1,000 to 5,000 m^3 (normal)/hr and a production of about 15 thousand tons a day, a preferable position thereof is about 5 m or more at downstream side from the ignition furnace.

[0039] According to the producing method of the present invention, the feed position of the diluted gaseous fuel is preferably at one or more arbitrary points after forming the sintered cake at exit side of the ignition furnace in the pallet moving direction, between the position where the combustion front propagates to below the surface layer, (for example, 100 mm or more of depth below the surface layer, preferably about 200 mm or less of depth where the combustion of the gaseous fuel begins), and the position of completion of the combustion. This means that the gaseous fuel feed begins at a stage when the combustion front moves to below the surface layer in the sintering bed, as described above, which means that the combustion of the gaseous fuel propagates inside the sintering bed and that the combustion successively moves to lower layer, which suggests that the danger of explosion is eliminated and that safe operation is available.

[0040] According to the producing method of the present invention, the feed of diluted gaseous fuel into the sintering bed also means to enhance the reheating of the formed sintered cake. That is, the sintered cake with low cold strength of sintered ore tends to become insufficient heat under the inherent condition of short holding time in high temperature zone. By feeding the gaseous fuel having higher reactivity than that of the feed of the solid fuel to that portion, the regeneration and widening of the combustion and melting zone is attained, thereby letting the feed of the gaseous fuel play a role of compensation of the combustion heat at that portion of likely lacking the heat.

[0041] In the producing method of sintered ore according to the present invention, it is preferable that at least a part of the gaseous fuel fed from above the sintering bed after ignition is sucked (introduced) down to the combustion and melting zone in the unburned state, then letting the fuel combust at the target position. The reason is that it should be more effective for the feed of gaseous fuel, or of injection into the sintering bed, to extend not only to the upper portion of the sintering bed but also to the combustion and melting zone at the center portion in the thickness direction. When the feed of gaseous fuel is given to upper layer portion of the sintering bed, where lack of heat (insufficient holding time in high temperature zone) likely occurs, sufficient combustion heat can be supplied, thus improving the quality (sinter strength) at that portion. When the action of the gaseous fuel feed propagates to a zone of intermediate portion or deeper portion, the effect becomes equivalent to the formation of re-combustion and melting zone over the inherent combustion and melting zone, which increases the thickness of the zone in the vertical direction. Consequently, the holding time in high temperature zone can be extended without increasing the ultimate maximum temperature, which allows actualizing the sufficient sintering without decreasing the pallet moving speed. As a result, the quality improvement of sintered cake (improvement of cold strength) of entire sintering bed can be achieved, and both the quality (cold strength) and the productivity of the product sintered ore can be improved.

[0042] According to the present invention, the feed of a diluted gaseous fuel has the first characteristic of adjusting the position of feeding the diluted gaseous fuel from the viewpoint that the selection of the position of the action and effect of the feed thereof, and has the second characteristic of degree of adjustment of the ultimate maximum temperature and the holding time in high temperature zone in the sintering bed, together with the feed of the fuel, responding to the amount of the solid fuel under the scheme of constant heat.

[0043] According to the present invention therefore, on feeding the diluted gaseous fuel into the sintering bed, it is preferable not only to adjust the feed position but also to adjust the form of the combustion and melting zone itself, and further to adjust the ultimate maximum temperature and/or the holding time in high temperature zone in the combustion and melting zone.

[0044] Generally in the sintering bed after ignition, the position of the combustion and melting zone varies with the propagation of combustion (flame) front to downward and frontward (to downstream side) accompanied with the pallet movement, as shown in FIG. 4(a). Then, as shown in FIG. 4(b), the heat history subjected in the sintering process in the sintering layer differs among upper layer, intermediate layer, and lower layer, and as shown in the figure, the holding time in high temperature zone largely differs between the upper layer and the lower layer, (about 1200°C or more). As a result, the sintering layer gives a yield distribution as shown in Fig. 4 (c) . That is, the yield in the surface layer portion (upper layer) is low, and that in the intermediate layer and the lower layer increases. To this point, when the gaseous fuel is fed in accordance with the method of the present invention, the combustion and melting zone varies to increase the thickness and the range in the vertical direction, which reflects the improvement in the quality of the product sintered ore. Since the intermediate layer and the lower layer which give high yield distribution can further adjust the holding time in high temperature zone, the yield can further be increased.

[0045] The adjustment of feed position of the gaseous fuel allows the adjustment of the form of the combustion and melting zone, or the thickness of the zone in the height direction and/or the width in the pallet moving direction, and also allows the adjustment of the ultimate maximum temperature and the holding time in high temperature zone. Those adjustments further increase the effect of the present invention, and achieve the sustained and sufficient firing through the increase in the thickness of the combustion and melting zone in the vertical direction and through the adjustments of the ultimate maximum temperature and the holding time in high temperature zone, thereby effectively contributing to the increase in the cold strength of the product sintered ore.

[0046] According to the present invention, the feed of the gaseous fuel to the sintering bed can also perform the adjustment of cold strength of entire product sintered ore. That is, the object of the injection of the gaseous fuel is to improve the cold strength of the sintered cake and further of the sintered ore. Specifically the object is to bring the cold strength (shutter index SI) of the sintered ore 75% or more to about 85%, preferably 80% or more, and more preferably 90% or more, through the adjustment of the feed position of gaseous fuel, the adjustment of the holding time in high temperature zone such as the retention time of the sintering raw material in the combustion and melting zone, and the adjustment of the ultimate maximum temperature.

[0047] According to the present invention, that strength level can be attained at low cost through the adjustment of specifically the concentration, the feed amount, the injection position, and the injection range of the gaseous fuel, preferably considering the amount of carbonaceous material in the sintering raw material (under a condition of keeping the entering heat to a constant level). The improvement of the cold strength of the sintered ore may lead to the increase in the gas flow resistance and to the deterioration in the productivity. The present invention, however, solves the problems by adjusting the ultimate maximum temperature and the holding time in high temperature zone, and increases the cold strength of the sintered ore. For the above cold strength, or SI value, the sintered ore manufactured by a commercial sintering machine gives higher SI value (by 10 to 15%) than that of the pot test.

[0048] According to the producing method of the present invention, the adjustment of feed position of the gaseous fuel in the pallet moving direction is determined on the basis of the target cold strength of the sintered ore in an arbitrary zone between the zone of sintered cake formed in the sintering bed and the wet zone. For conducting the adjustment, the present invention adjusts the scale (size), the amount, and the position (distance from the ignition furnace) of the gaseous fuel charge apparatus, and the gas concentration, preferably responding to the amount of carbonaceous material (solid fuel) in the sintering raw material, thus adjusting not only mainly the size of the combustion and melting zone (in the vertical direction and width in the pallet moving direction) but also the ultimate maximum temperature and the holding time in high temperature zone, thereby adjusting the strength of the sintered cake formed in the sintering bed.

[0049] According to the producing method of the present invention, the gaseous fuel preferably adopts blast furnace gas, coke oven gas, a mixed gas of blast furnace gas and coke oven gas, propane gas, natural gas, methane, or a mixed gas of them. Each of those gases contains combustion component, and the gas is diluted by air or the like to prepare a gaseous fuel having a concentration of 75% or less of the lower limit concentration of combustion. The dilution of the gaseous fuel may be done by, other than air, an inert gas, inert gas and oxygen, inert gas and air, or air and oxygen.

[0050] On executing the method for producing sintered ore according to the present invention, the applied sintering machine is a downward suction type DL sintering machine having a pallet on which the sintering bed of sintering raw material is formed to move in circulation, a suction wind box located below the pallet, a raw material charge apparatus on the pallet, an ignition furnace on the pallet at downstream side in the pallet moving direction, wherein a gaseous fuel feed apparatus is located at downstream side of the ignition furnace to inject the gaseous fuel diluted to a concentration of below the lower limit concentration of combustion into the sintering bed from above thereof.

[0051] According to the present invention, it is preferable that the gaseous fuel feed apparatus is located so as to extend over both side walls of the pallet along the width direction of the sintering machine. The gaseous fuel feed apparatus is preferably structured by an injection hood which feeds the diluted gaseous fuel, or an injection hood which also has rows of injection pipes in slit shape or in plane pattern for the gaseous fuel or the diluted gaseous fuel.

[0052] The gaseous fuel feed apparatus is preferably arranged one or more at a position of downstream side of the ignition furnace and in the pallet moving direction in the progress of the combustion and melting zone through the sintering bed, thus the feed of the gaseous fuel into the sintering bed is preferably given at a position after the ignition of the carbonaceous material in the sintering bed. That is, the apparatus is placed by one or more at an arbitrary position of downstream side of the ignition furnace and of propagation of the combustion front below the surface layer. The size, the position, and the quantity of the apparatus are adjusted from the viewpoint of adjusting the target cold strength of the product sintered ore. The gaseous fuel feed apparatus is preferably located at a position in the low yield portion near both side walls, and the gaseous fuel preferably uses a flammable gas diluted to 75% or less and 2% or more of the lower limit concentration of combustion, and more preferably uses a flammable gas diluted to 60% or less and 2% or more of the lower limit concentration of combustion.

[0053] According to the present invention as described above, operation of the downward suction type sintering machine allows the combustion at a target position in the sintering bed by feeding a diluted gaseous fuel from above the sintering bed, and further the operation allows increasing the strength of sintered ore not only in the upper portion of the sintering bed where combustion likely becomes insufficient and the cold strength of the sintered ore likely decreases but also in an arbitrary portion at or below the intermediate layer of the sintering bed by adjusting the feed position of the diluted gaseous fuel, the ultimate maximum temperature during combustion, and the holding time in high temperature zone. In addition, the present invention allows adjusting the strength of sintered cake at an arbitrary position through specifically the reaction in the combustion and melting zone, for instance the adjustment of thickness of the zone in the vertical direction and the adjustment of width in the pallet moving direction, without deteriorating the gas permeability of entire sintering bed. Consequently, the product sintered ore having high cold strength can be manufactured over the entire sintered ore while assuring good yield and high productivity. With the use of the sintering machine of the present invention, the operation of the sintering machine can be stably attained.

[0054] FIG. 5 illustrates an embodiment of the apparatus for producing sintered ore according to the present invention. The present invention, however, is not limited to the structure given in the example. A gaseous fuel feed apparatus (hood) 12 for injecting gaseous fuel such as a mixed gas (M gas) of blast furnace gas and coke oven gas is positioned by only one unit at upper side of the sintering bed at downstream side of an ignition furnace 10 in the pallet moving direction. The gaseous fuel feed apparatus 12 is composed of pluralities of pipe-shaped gas injection nozzles 12a facing downward in pluralities of rows in the machine width direction. The pluralities of pipe-shaped gas injection nozzles 12a are arranged to cover the sintering bed above the side walls (not shown) via the gaseous fuel feed apparatus 12. The M gas which is fed from the gaseous fuel feed apparatus 12 is sucked down to a deep portion (lower layer) of the sintering bed from above thereof via the sintered cake formed at the surface layer by the suction force of the wind box 11 below the pallet 8. When the improvement of the yield is aimed at the region of as low as 60% yield, shown in FIG. 4(c), it is preferable that the nozzles 12a are arranged so as to feed a large amount of gaseous fuel to a position near both side walls of the pallet.

[0055] Applicable gaseous fuel being fed from the gaseous fuel feed apparatus 12 includes blast furnace gas (B gas), coke oven gas (C gas), a mixed gas (M gas) of blast furnace gas and coke oven gas, propane gas, natural gas (LNG), methane, and a diluted mixture of them. These gaseous fuels may be fed by a separate piping system, independent from the ignition furnace 10. Alternatively, they may be fed by a common pipe to the fuel pipe for ignition furnace, specifically along with the diluted gas introduction pipe, thus connecting to the extended gas feed pipe (not shown) for the ignition furnace 10 after diluted and adjusted the concentration of the gaseous fuel to below the lower limit concentration of combustion.

[0056] TABLE 1 shows examples of gas concentration for varieties of gaseous fuels applied to the present invention, in terms of lower limit concentration of combustion and upper limit concentration for injection, (75%, 60%, and 25%).

[0057] For propane gas, as an example, the lower limit concentration of combustion is 2.2% by volume, the upper limit concentration of injection gas diluted to 75% is 1.7% by volume, the upper limit concentration of injection gas diluted to 60% is 1.3% by volume, and the concentration of injection gas diluted to 25% is 0.4% by volume. The concentration begins to show the injection effect, or the lower limit concentration of diluted injection gas is 0.05% by volume. Therefore, the respective preferable ranges are the following.

Preferable range (1): 2.2% by volume to 0.05% by volume

Preferable range (2): 1.7% by volume to 0.05% by volume
Preferable range (3): 1.3% by volume to 0.05% by volume
Preferable range (4): 0.4% by volume to 0.05% by volume

[0058] For C gas, the lower limit concentration of combustion is 5.0% by volume, the upper limit concentration of injection gas diluted to 75% is 3.8% by volume, the upper limit concentration of injection gas diluted to 60% is 3.0% by volume, and the concentration of injection gas diluted to 25% is 0.9% by volume. The concentration begins to show the injection effect, or the lower limit concentration of diluted injection gas is 0.24% by volume. Therefore, the preferable ranges are the following.

Preferable range (1): 5.0% by volume to 0.24% by volume
Preferable range (2): 3.8% by volume to 0.24% by volume
Preferable range (3): 3.0% by volume to 0.24% by volume
Preferable range (4): 0.9% by volume to 0.24% by volume

[0059] For LNG, the lower limit concentration of combustion is 4.8% by volume, the upper limit concentration of injection gas diluted to 75% is 3.6% by volume, the upper limit concentration of injection gas diluted to 60% is 2.9% by volume, and the concentration of injection gas diluted to 25% is 0.9% by volume. The lower limit concentration of diluted injection gas is 0.1% by volume. Therefore, the preferable ranges are the following.

Preferable range (1): 4.8% by volume to 0.1% by volume
Preferable range (2): 3.6% by volume to 0.1% by volume
Preferable range (3): 2.9% by volume to 0.1% by volume
Preferable range (4): 0.9% by volume to 0.1% by volume

[0060] For blast furnace gas, the lower limit concentration of combustion is 40.0% by volume, the upper limit concentration of injection gas diluted to 75% is 30.0% by volume, the upper limit concentration of injection gas diluted to 60% is 24.0% by volume, and the concentration of injection gas diluted to 25% is 7.6% by volume. The lower limit concentration of diluted injection gas is 0.24% by volume. Therefore, the preferable ranges are the following.

Preferable range (1) : 40.0% by volume to 1.25% by volume
Preferable range (2) : 30.0% by volume to 1.25% by volume
Preferable range (3) : 24.0% by volume to 1.25% by volume
Preferable range (4): 7.6% by volume to 1.25% by volume TABLE 2 shows the content and calorific value of hydrogen, CO, methane, ethane, and propane as the combustion components of C gas, LNG, and B gas.

TABLE 1

Gas	Lower limit concentration of combustion %, to Air (lower limit of explosion)	Upper limit concentration for injection %, to Air (75%)	Upper limit concentration for injection %, to Air (60%)	Upper limit concentration for injection %, to Air (25%)	Ignition temperature in Air, °C
Propane	2.2	1.7	1.3	0.4	528-588
Hydrogen	4.0	3.0	2.4	0.8	580-590
Methane	5.0	3.8	3.0	0.9	650-750
CO gas	12.5	9.4	7.5	2.3	658-674
Coke oven gas	5.0	3.8	3.0	0.9	about 630
LNG	4.8	3.6	2.9	0.9	about 680
Blast furnace gas	40.0	30.0	24.0	7.5	about 680

TABLE 2

	Hydro gen (vol%)	Nitrogen (vol%)	CO (vol%)	CO_2 (vol%)	Methane (vol%)	Ethane (vol%)	Propane (vol%)	Calorific value (Mcal/M3)
C gas	59	-	7	-	34	-	-	4.8
LNG	-	-	-	-	89	5	6	9.5
B gas	4	61	24	21	-	-	-	0.8

[0061] The following is the description of an experiment which is the starting point of the development of the method for producing sintered ore according to the present invention.

[0062] The experiment is an example of operation of the following. An experimental apparatus is the one shown in FIG. 6, or a test pot in vertical tubular shape (150 mm in diameter and 400 mm in height) equipped with a transparent quartz window. The gaseous fuel is a mixed gas (M gas) of blast furnace gas and coke oven gas. The applied sintering raw material is the same to that used in a sintering plant of the inventors of the present invention, or the sintering raw material given in TABLE 3. The downward suction pressure is constant level of 11.8 KPa. The concentration of the combustion component in the M gas is diluted by air to vary in a range from 0.5 to 15% by volume. The lower limit concentration of combustion of the M gas is 12% by volume.

TABLE 3

Grade of raw material	Fraction (mass%)
Robe River	9.6
Yandi	23.8
Carajas	42.6
Limestone	16.6
Silica rock	2.7
Coke fine	4.7

[0063] FIG. 6 also shows the condition observed through the transparent quartz window by video, specifically the descending behavior accompanied with the propagation of combustion front. As seen in FIG. 6, when a gaseous fuel containing 15% by volume of M gas, exceeding the lower limit concentration of combustion (12% by volume), was injected into the raw material packed layer in the test pot, the gaseous fuel immediately began combustion at the surface of the sintering bed, thus failing to reach the lower layer of the sintering bed, and attaining only a small effect of injection. To the contrary, following the method of the present invention, when a gaseous fuel diluted by air to 3% by volume, below 75% of the lower limit concentration of combustion (12% by volume) of the gaseous fuel, was used, combustion on the surface of the raw material packed layer did not occur, and the gaseous fuel reached deep into the sintering bed, or to a zone equivalent to the combustion and melting zone. As a result, compared with the thickness of the combustion zone (also called the "combustion and melting zone") on sintering in air of 70 mm, the example increased the thickness of the combustion zone to 150 mm, or more than two times. That is, the increase in the thickness of the combustion zone is a result of extension of the holding time in high temperature zone.

[0064] In addition in the experiment with the test pot, the descending speed of the combustion zone, (the inverse value thereof is the sintering time), corresponding to the propagation of the combustion front accompanied with the travel of the pallet in the commercial sintering machine, increased with the feed of the diluted gaseous fuel, and increased the thickness of the combustion zone in the vertical direction similar to the case of increased amount of coke and to the case of injection of hot air. When a gaseous fuel diluted to an adequate concentration was injected into the sintering bed of the sintering raw material, it was found that the extending effect of the thickness of the combustion zone becomes significant compared with the conventional cases of using solid fuel, liquid fuel, or non-diluted flammable gas, and that the descending speed of the combustion front proceeds almost the same to the case of sintering in air.

[0065] Figs 7(a) to (d) summarize the results of sintering pot tests in the above experiment. According to the results, when the M gas diluted to an adequate concentration was injected into the raw material sintering bed in accordance with the method of the present invention, the yield increased to some extent (FIG. 7(a)) and the sinter productivity also increased (FIG. 7(b)), though the sintering time changed very little. Furthermore, the shutter strength (SI) which is a control index of the cold strength largely affecting the operation performance of blast furnace also increased by more than 10% (FIG. 7(c)), and the reduction degradation index (RDI) increased by as large as 8% (FIG. 7(d)).

[0066] The present invention uses a diluted gas as the gaseous fuel being fed to the sintering bed. The degree of dilution is described below. TABLE 4 shows the lower limit of combustion and the upper limit of combustion for blast furnace gas, coke oven gas, a mixed gas (M gas) of blast furnace gas and coke oven gas, propane, methane, and natural gas, respectively. For example, if the gas having that combustion limit is not combusted in the sintering bed and is sent to a vent blower, the electric precipitator and other equipment in the gas passage have a possibility of explosion or combustion. To this point, the inventors of the present invention made trial and error experiments, and adopted a gaseous fuel which was diluted to a limit of not inducing the above possibility, or diluted to below the lower limit of combustion, and used a gaseous fuel having 75% or below the lower limit concentration of combustion to further increase the safety, and confirmed that no problem occurred in many experimental runs.

[0067] For example, the range of combustion of blast furnace gas is, as shown in TABLE 4, 40% by volume as the lower limit of combustion (that is, below 40% by volume does not induce combustion) in air at normal temperature, and 71% by volume as the upper limit of combustion. This means that, higher than 71% by volume gives excessively high concentration of the blast furnace gas, which case is also the not-combusting state. The basis of these values is described below referring to the drawings.

TABLE 4

		(vol%)
	Lower limit of combustion	Upper limit of combustion
Blast furnace gas	40.0	71
Coke oven gas	5.0	22
Mixed gas (M gas)	12.0	42

[0068] FIG. 8 shows an example of the method to determine the combustion limits of blast furnace gas. Regarding the amount of the combustion component (flammable gas) and other component (inert: inert gas) in the blast furnace gas, shown in FIG. 8, the combination of H_2 and CO_2, and CO and N_2 gives the following.

(1) For the combination of "H_2 and CO_2", the ratio of (inert gas)/(flammable gas) is 3.5/20.0 = 5.7.
Then, in the combustion limit diagram, the portion where the horizontal axis giving the ratio of (inert gas)/(flammable gas) at 5.7 crosses the (H_2+CO_2) curve, (the combustion limits), was determined. The result is 32% by volume for the lower limit and 64% by volume for the upper limit. That is, the lower limit of combustion of (H_2 + CO_2) is 32% by volume and the upper limit thereof is 64% by volume.
(2) For the combination of residual combustion component "CO and N_2", the ratio of (inert gas) / (flammable gas) is 53.5/23.0 = 2.3. Therefore, similarly the point of intersection of 2.3 on the horizontal axis and the (CO + N_2) curve gives 44% by volume for the lower limit of combustion and 74% by volume for the upper limit thereof. In this case therefore, the lower limit of combustion is 44% by volume and the upper limit thereof is 74% by volume.

[0069] Furthermore, the lower limit of combustion of blast furnace gas containing both combustion components is derived from the following formula.

$$\text{Lower limit of combustion} = 100/(23.5/32 + 76.5/44) \fallingdotseq 40\%$$

[0070] From the formula, if the upper limit of (1) and (2), respectively, is substituted thereto, the upper limit of combustion can be determined. With the procedure, the lower limit of combustion and the upper limit of combustion can be derived for the blast furnace gas.

[0071] Another reason to emphasize the lower limit of combustion of gaseous fuel in the present invention is described below. FIG. 9 shows the relation between the concentration of combustion component (combustion gas) of the gaseous fuel, in air at normal temperature, and the temperature, (refer to the "Combustion Handbook" of CORONA PUBLISHING CO., LTD.). Although the combustion limits can be determined as above, the combustion limits have a temperature dependency. For example, even when the lower limit of combustion at normal temperature (equivalent to the concentration of combustion gas in FIG. 9) is about 40% by volume, it varies in a range from 26 to 27% by volume in a 200°C region, and several percentages in a 1000°C region, and further it can combust even at less than 1% by volume in a 1200°C region.

[0072] The findings showed that safety is assured if the concentration of gaseous fuel (content of the combustion component) fed to the sintering bed is diluted to a safe region, or lower than the lower limit of combustion at normal temperature, and that the freedom of adjustment of the combustion position in the thickness direction (temperature distribution) in the sintering bed increases if only the concentration of the diluted gas is adjusted.

[0073] It was also found that the combustion of gaseous fuel has above-described temperature dependency, for example, the combustion range widens when the environmental temperature increases, that combustion proceeds in a temperature field near the combustion and melting zone of the sintering machine, and that combustion does not occur at a concentration given in the preferable examples of the present invention in a temperature field at about 200°C such as the position within the electric precipitator located at downstream side of the sintering machine.

[0074] On producing sintered ore, the gaseous fuel which is fed into the sintering bed of the sintering raw material is sucked by the wind box below the pallet, and is combusted in a high temperature region in the combustion and melting zone formed by the combustion of solid fuel (coke) in the sintering bed. Accordingly, when the feed of gaseous fuel is adjusted in terms of concentration and feed amount thereof under a condition to keep the heat entering the sintering bed constant, the amount of coke fine in the sintering raw material can be adjusted (decreased). The adjustment of concentration of gaseous fuel means to adjust the combustion of the gaseous fuel to begin at an expected position (in a concentration region) in the sintering bed.

[0075] In this respect, the combustion and melting zone in the sintering bed according to the conventional technologies indicates the zone of combusting only the solid fuel (coke fine). For the case of the present invention, however, the zone is the one to combust further gaseous fuel adding to the coke fine. Consequently, according to the present invention, when the conditions of concentration and feed amount of the gaseous fuel and of other feeding conditions are adequately varied in relation to the presumption of existence of coke fine as a part of the fuel, the ultimate maximum temperature and/or the holding time in high temperature zone can be adjusted to a desired state, thereby achieving the increase in the strength of sintered cake.

[0076] Another reason of using a diluted gaseous fuel in the present invention is to adjust the strength and the yield of the sintered cake through the above-described adjustment of form of the sintering and melting zone. That is, the role of the diluted gaseous fuel effectively functions to adjust the holding time and the ultimate temperature of the sintered cake in the high temperature zone (combustion and melting zone). In other words, the use of the gaseous fuel means the adjustment so as the sintering raw material to elongate the holding time in high temperature zone and to increase the ultimate maximum temperature to an adequate level. That adjustment means to use the gaseous fuel which is diluted and adjusted so as to assure a proper amount of the combustion support gas (air or oxygen) in the combustion atmosphere responding to the amount of solid fuel (coke fine) in the sintering raw material. To this point, the conventional technologies inject the combustion support gas without adjusting the concentration and independent of the amount of the solid fuel in the sintering raw material, thus induces insufficient amount of the combustion support gas (oxygen) for the amount of solid fuel and of flammable gas, thereby resulting in insufficient combustion, or inversely induces over-combustion locally to result in non-uniform strength. The present invention can avoid those problems by using the gaseous fuel after adjusting the dilution degree.

[0077] The effect of diluted gaseous fuel fed after diluting the gas responding to individual gaseous fuel types is described below. FIG. 10 shows the conditions and the results of comparison experiments between the conventional sintering method (without injection of gaseous fuel) and the sintering method of the present invention using a gaseous fuel diluted to below the lower limit of combustion. The conventional sintering method not injecting diluted gaseous fuel is an example of use of coke fine by 5%. As an example of the present invention injecting the diluted gaseous fuel, the amount of added coke fine is 4.2% by mass to keep the total heat constant by injecting the diluted gaseous fuel equivalent to 0.8% of coke fine. For both cases, the example of use of diluted gaseous fuel showed improvement in the shutter strength, the product yield, and the productivity. For the example of using diluted gaseous fuel, the improvement in the shutter strength, the product yield, and the like presumably came from the widening of the combustion and melting zone indicated as the combustion state, and is given as the result of extended holding time in high temperature zone.

[0078] FIG. 11 shows the effect of concentration of injection gas when propane gas and C gas are used as the gaseous fuel, giving the relation of the concentration of diluted gaseous fuel and each of the shutter strength (a), the yield (b), the sintering time (c), and the productivity (d). As seen in the graphs, when propane gas is used as the diluted gaseous fuel, the improvement in the shutter strength appears at the addition of 0. 05% by volume, and the yield shows almost equal effect. Distinctive effect appears for the propane gas from 0.1% by volume, preferably from 0.2% by volume. As the C gas conversion, the effect appears from 0.24% by volume of addition, preferably from 0.5% by volume, and distinctive improvement effect appears from 1.0% by volume. Consequently, for the propane gas, the necessary addition is at least 0.05% by volume, preferably 0.1% by volume or more, and more preferably 0.2% by volume or more. For the C gas, the necessary addition is at least 0.24% by volume, preferably 0.5% by volume, and most preferably 1.0% by volume, and the upper limit is 75% or less of the lower limit concentration of combustion. For the case of propane gas, addition by 0.4% by volume almost saturates the effect, and the gas concentration at that moment corresponds to 25% of the lower limit concentration of combustion.

[0079] The next description is about the cold strength and the reduction degradation index (RDI) of the sintered ore manufactured in accordance with the method of the present invention, charging the gaseous fuel taking into account of the amount of carbonaceous material in the sintering raw material. According to "Mineral Engineering (KOBUTSU KOGAKU)", edited by Hideki Imai, Sukune Takenouchi, and Yoshinori Fujiki, p.175 (1976), Asakura Publishing Co., Ltd., the schematic diagram of the sintering reaction is summarized in FIG. 12. TABLE 5 shows the tensile strength (cold strength) and the reducing property value for individual minerals formed in the sintering process. As seen in FIG. 12, the sintering process begins the formation of melt at 1200°C, thus forming calcium-ferrite which has the highest strength among the ores structuring the sintered ore and has relatively high reducing property. At a further high temperature to exceed about 1380°C, the calcium-ferrite decomposes to an amorphous silicic compound (calcium-silicate) which has the lowest cold strength and reducing property among the structuring minerals, and to a secondary hemantite which is likely reduced and powdered. Therefore, to improve the cold strength and RDI of sintered ore, there is an issue that the calcium-ferrite is to be stably and sustainably formed without decomposing thereof.

TABLE 5

	Tensile strength (MPa)	Reducing property (%)
Hematite	49	50
Magnetite	58	22
Calcium-ferrite	102	35
Calcium-silicate	19	3

[0080] According to the description of above "Mineral Engineering", the behavior of precipitation of secondary hematite which acts as the origin of reduction degradation of the sintered ore is described as illustrated in FIG. 13. According to the description, mineral synthesis tests revealed that the skeleton crystalline secondary hematite which acts as the origin of the reduction degradation precipitates after being heated to (Mag.ss + Liq) zone, and after cooled. Accordingly, the description derives that the reduction degradation can be suppressed by producing the sintered ore through the (2) route, not through the (1) route on the diagram. Therefore, to manufacture a low RDI sintered ore and a high strength sintered ore, it is important to attain a heat pattern holding for a long period within the sintering bed between the temperature range from 1200°C (the temperature of solid phase line of calcium-ferrite) to about 1380°C (transition temperature). Consequently, it is concluded that the ultimate maximum temperature in the sintering bed, in which the amount of adding carbonaceous material is adjusted by the feed of the gaseous fuel, is regulated to a range from above 1200°C to below 1380°C, and preferably from 1205°C to 1350°C.

[0081] To confirm the relation between the width of the combustion zone and the diluted fuel gas, the inventors of the present invention conducted an experiment, using a vertical tubular test pot equipped with a transparent quartz window, of injecting propane gas which was diluted by flue gas of the sintering machine cooler into the sintering bed of the sintering raw material from above the pot. The applied sintering raw material was an ordinary one used by the company of the inventors of the present invention. The suction pressure was kept constant at 1200 mmH_2O. The concentration of the injected propane gas was diluted to 0.5% by volume and 2.5% by volume, respectively. The entered heat at the injection of 0.5% by volume of propane gas nearly corresponded to 1% by mass of coke fine.

[0082] FIG.14 shows photographs of observed combustion zone on injecting propane gas in the experiment. As seen in FIG. 14, the propane gas which was diluted to 2.5% by volume combusted immediately after the injection on the raw material sintering bed, and the gaseous fuel did not enter into the sintering bed, thus no effect was attained. With the propane gas of 0.5% by volume of diluted concentration to air, the gas did not combust in upper portion of the sintering bed, and entered into the sintering bed, and then combusted within the sintering bed at a high combustion rate. As a result, compared with the vertical width of the combustion zone of about 70 mm under the sintering under atmospheric condition, the injection of that diluted propane gas widened the vertical width of the combustion zone (corresponding to the holding time in high temperature zone) to 150 mm, or more than two times.

[0083] Consequently, it was confirmed that the effect of widening in the thickness of combustion zone appears even at 0.5% by volume, which is one fifth of the lower limit concentration of combustion of propane, 2.5% by volume (theoretical value, to air). Inversely, it was found that, with the technology of gaseous fuel injection according to the present invention, the combustion adjustment in the sintering bed is difficult unless a diluted gaseous fuel is applied.

[0084] Furthermore, the experiment investigated the descending speed of the combustion zone, (inverse thereof is the holding time in high temperature zone). When simply the amount of coke was increased, or when high temperature air was injected, the descending speed significantly decreased to deteriorate the productivity. However, when a diluted gaseous fuel was applied, the combustion rate remarkably increased compared with the example of using a solid fuel, thus the descending speed of the combustion zone gave almost the same to that of the case of atmospheric air sintering.

[0085] Next, the inventors of the present invention investigated the effect of the injection position of diluted gaseous fuel.

[0086] TABLE 6 shows the specification of the experiment. Test No. 1 is under the condition of 5% by mass of coke in the sintering raw material, or current base condition. Test No. 2 is under the condition of 4% by mass of coke fine therein, decreasing the content of coke fine by 1% by mass, while injecting 0.5% by volume of propane gas to keep the entering heat constant. Test No. 3 is under the condition of 10% by mass of coke fine. Test No. 4 is under the condition of injecting 450°C hot gas in order to verify the difference from the soaking furnace (JP-A-60-155626).

TABLE 6

Test No.	No. 1	No. 2	No. 3	No. 4
Coke fine ratio (to raw material, mass%)	5	4	10	5
Propane concentration (to Air, vol%)	0	0.5	0	0
Soaking furnace (injection of 450°C hot air)	OFF	OFF	OFF	ON

[0087] FIG. 15 shows the results, giving an example of using coke oven gas (C gas) diluted to 2% as the gaseous fuel. FIG. 15 gives the results of investigation on the gaseous fuel injection in terms of the relation of the injection position, the shutter strength of the product sintered ore, and the product yield. The injection position of the diluted gaseous fuel was selected to the position of "100 to 200 mm" from the surface of the sintering bed, the position of "200 to 300 mm" therefrom, and the position of "300 to 400 mm" therefrom, respectively. At the injection position of "100 to 200 mm" in the figure, the diluted gaseous fuel was fed from above the test pot after the combustion and melting zone (bright (white) indication) moved to the 100 mm position, thereby combusting the diluted gaseous fuel in the combustion and melting zone while the injection position remained at the "100 to 200 mm" position. Similarly, at the position of "200 to 300 mm", the diluted gaseous fuel was fed from above the test pot at a stage that the combustion and melting zone reached the 200 mm position, and similarly at the position of "300 to 400 mm", the diluted gaseous fuel was fed at a stage that the combustion and melting zone reached the position of 300 mm. For reference, FIG. 15 also gives the combustion and melting zone in the conventional method in terms of the above respective positions of layer without injecting the diluted gaseous fuel.

[0088] The combustion air fed to the test pot flows downward from top, similar to the case of ordinary sintering operation. On feeding the gaseous fuel, the gaseous fuel is added to the combustion air to a specified concentration before charging.

[0089] In FIG. 15, the combustion and melting zone is shown in bright (white). In the region from 100 to 200 mm, the combustion and melting zone was slightly thicker than that in the conventional method. In the region from 200 to 300 mm, the thickness of the combustion and melting zone distinctively increased compared with the conventional method. Also the region from 300 to 400 mm, there gave distinctive difference from the conventional method.

[0090] From the above result, for attaining the effect of the injection of diluted gaseous fuel, it is preferable that the charge of gaseous fuel is given to the combustion and melting zone portion on the pallet of the sintering machine, which portion is at or deeper than 200 mm below the surface of the sintering bed. That injection also decreases the cost of applied gaseous fuel. For the region shallower than 200 mm from the surface of the sintering bed, the yield of the product sintered ore can be totally improved because the shutter strength of the sintered ore significantly increases by charging the diluted gaseous fuel to the region of 200 mm or deeper without forcefully feeding the gaseous fuel to the region shallower than 200 mm.

[0091] FIG. 16 shows sketches of combustion state at upper layer portion between the surface and less than 200 mm depth of the sintering bed, at intermediate and lower layer portions at or deeper than 200 mm. The arrow A in the figure indicates the propagation direction of the sintering (fuel direction). FIG. 16(a) shows the combustion position of coke fine and gaseous fuel in the upper layer portion (< 200 mm). In this case, the combustion zone being formed by the coke fine fuel is inherently narrow at upper portion of the sintering bed, and the combustion zone of the coke fine and the combustion point of gaseous fuel which combusts in the combustion zone are close to each other, thus the temperature pattern given at right side of the figure is established. In the temperature distribution, the combustion zone of coke fine (solid fuel) is expressed by hatched area, and the temperature zone of gaseous fuel combusting above therefrom is expressed by not-hatched area. As shown in FIG. 16(a), at the upper portion of the sintering bed, the combustion of coke and the combustion of gaseous fuel occur at the same time (both combust at close position with each other) so that the holding time in high temperature zone (corresponding to about 1200°C), given between T_1 and T_2, becomes short as shown in the figure. That is, the temperature distribution allows only slightly widened coke combustion zone shown by the hatched area. As derived before that the feed of the gaseous fuel is preferably done after the thickness of the combustion and melting zone becomes 15 mm or more, the phenomenon agrees with that the effect of injection of gaseous fuel is poor when the original holding time in high temperature zone is short. On the other hand, FIG. 16(b) shows the case of feeding the gaseous fuel into intermediate and lower layer portions. In the intermediate and lower layer portions, the combustion zone width increases with the propagation of combustion zone from upper layer downward, also supported by the increase in the temperature of sintering bed, thus the combustion occurs at a position more distant from the case of FIG. 16(a). As a result, the temperature distribution becomes that given at right side of FIG. 16(b). That is, the combustion point of gaseous fuel is distant from the combustion point of solid fuel (coke) expressed by hatched area, thus the synthesized temperature distribution curve becomes a wide-base distribution. As a result, the holding time in high temperature zone based on the combustion of solid fuel and of gaseous fuel, given by T_3 and T_4, respectively, extends to increase the shutter strength of the obtained sintered ore.

[0092] For the case of FIG. 16(b), the ignition temperature of the gaseous fuel for adjusting the holding time in high temperature zone is preferably in a range from 400°C to 800°C, and more preferably from 500°C to 700°C. If the ignition temperature is below 400°C, the high temperature zone does not widen, and simply the distribution of low temperature zone widens. If the ignition temperature exceeds 800°C, the holding time becomes too close to the holding time in high temperature zone of the combustion of solid fuel, thus giving small effect of extending the holding time in high temperature zone.

[0093] An example of the method to adjust the ultimate maximum temperature in the sintering bed by feeding the diluted gaseous fuel is described below. FIG.17 is a schematic drawing of the temperature distribution during sintering. The figure illustrates the sintering method according to the present invention, on the basis of the conventional sintering method with a temperature distribution example of addition of 5% by mass of solid fuel (coke fine). For instance, in a sintering operation with the addition of 5% by mass of coke, the conventional sintering method is given by the curve "a". Generally, to extend the holding time in high temperature zone, increase in the quantity of coke fine is effective. As shown in the figure, for example, the case of the addition of 10% by mass of coke fine is expressed by the broken line "a'". Although the holding time in high temperature zone expressed by the bed height widens from (0 - A) to (0 - B), the maximum temperature also increases from about 1300°C to about 1370°C to 1380°C, which fails to attain the low RDI sintered ore and the high strength sintered ore.

[0094] In this regard, the sintering operation method according to the present invention can suppress the ultimate maximum temperature to 1270°C and widens the holding time in high temperature zone to (0 - C) owing to the injection of diluted C gas while suppressing the use amount of coke fine to 4.2% by mass, the object of producing low RDI and high strength sintered ore, which cannot be achieved by the conventional method, is fully attained.

[0095] In short, the conventional sintering method is an operational method focusing on either of the holding time in high temperature zone or the adjustment of maximum temperature. To this point, the method according to the present invention is an operational method that adjusts the ultimate maximum temperature (1205°C to 1350°C) by adjusting the amount of coke fine (for example, suppressing to 4.2% by mass), and that adjusts also the holding time in high temperature zone by the injection of diluted gaseous fuel. The curve "d" in FIG. 16 is an example of simply decreasing the amount of solid fuel to 4.2% by mass, thus giving low ultimate maximum temperature and short holding time in high temperature zone.

[0096] FIG. 18 is an example of conventional sintering method, using 5% by mass of coke fine, and an example compatible to the present invention, using 4.2% by mass of coke fine and injecting a C gas diluted to 2.0% by volume. As seen from the Thermobias in the figure, the conventional method generated a combustion state exceeding 1400°C to maintain the holding time in high temperature zone. For the case that the amount of coke fine was limited to 4.2% by mass and that the C gas of 2% by volume was injected, the 1400°C region disappeared, the ultimate maximum temperature was regulated to 1350°C or below, and the holding time in high temperature zone could be extended.

[0097] FIG. 19 shows the variations of internal temperature of sintering bed (a), flue gas temperature (b), gas flow rate (c), and flue gas composition (d) with time resulting from the injection of diluted propane gas under a condition of constant entering heat. The internal temperature of sintering bed is an observed value in the test pot using a thermocouple inserted at a position of 200 mm above the grate bar, (thickness of sintering bed: 600 mm). The measurement was given at two points in the circumferential direction of the test pot, namely at the center and at 5 mm from the wall. From these figures, it was confirmed that the injection of diluted propane gas increased the time of keeping melt of the sintering raw material heated to 1205°C or higher temperature, (hereinafter referred to as the "holding time in high temperature zone"), by two times or more, and the ultimate maximum temperature did not increase. By injecting a diluted propane gas, the oxygen concentration in the flue gas decreased, which suggests that oxygen efficiently contributed to the combustion reaction.

[0098] FIG. 20 compares the variations of internal temperatures of the sintering bed with time, (a) and (a'), and of flue gas concentrations with time, (b) and (b'), resulting from the injection of diluted propane (0.5% by volume) and from the increase only the coke (10% by mass). These figures showed that, although the case of doubling the use amount of the coke fine gave the holding time in high temperature zone at 1200°C or above almost equal to that in the case of injection of a propane gas diluted to 0.5% by volume, the ultimate maximum temperature exceeded 1350°C. In addition, it was confirmed that increase in the amount of coke fine significantly increased the CO_2 concentration in the flue gas from 20% by volume to 25% by volume, and increased the CO concentration, thus the contribution of coke fine to the combustion becomes small.

[0099] FIG. 21 summarizes the results of various characteristics in above tests. As clearly shown in FIG. 21, although the injection of diluted propane gas increased the sintering time to some extent, the yield, the shutter strength, and the productivity improved, and also the reduction degradation index (RDI) and the reducing property significantly improved. Consequently, it was confirmed that, by optimizing the injection of diluted gaseous fuel, the high quality of sintered ore can be attained together with the improvement of productivity and yield.

[0100] On the other hand, for the case of simply increasing sole coke fine to 10% by mass, the sintering time increased and the ultimate maximum temperature excessively increased, thus the low strength amorphous silicic compound was formed in an excessive volume, thereby remarkably deteriorated both the shutter strength and the yield. For the case of 450°C soaking furnace, the improvement effect of shutter strength and yield became small, which almost agreed with the results observed in commercial facilities.

[0101] As understood from the above description, when a diluted gaseous fuel is applied, the gas combusts in the sintering bed to widen the combustion zone in the layer and also to form a wide combustion zone owing to a synergy effect of the combustion heat of coke in the sintering raw material and the combustion heat of the diluted propane gas. As a result, the ultimate maximum temperature did not excessively increase, while the holding time in high temperature zone was extended by the combustion of charged diluted gas.

[0102] Then, the inventors of the present invention investigated the effect of the injection of diluted gaseous fuel on the reducing property, the cold strength, and other characteristics of the product sintered ore, comparing with those in the conventional method (5% by mass and 10% by mass of coke; injection of hot air). The measured items are the composition of minerals in the product sintered ore, (affecting the cold strength and the reducing property), the apparent specific gravity (affecting the cold strength), and the distribution of pore size of 0.5 mm or smaller (affecting the reducing property).

[0103] FIG. 22 shows the result of determined composition of the mineral phase in the product sintered ore, quantified by the powder X-ray diffractometry. FIG. 22 suggests that, when the entered heat is constant (coke 4% by mass + propane 0.5% by volume), using both the solid fuel and the diluted propane gas, the calcium-ferrite is stably formed, which then improves the reducing property and increases the cold strength.

[0104] FIG. 23 gives the observed result of apparent specific gravity of product sintered ore, and FIG. 24 gives the observed result of distribution of pore size of 0.5 mm or smaller using a mercury intrusion porosity meter. FIG. 22 suggests that the injection of diluted propane gas conducts heating from outside of the granulated particles, thus the melt flow is enhanced, which decreases the porosity of 0.5 mm or larger, (apparent specific gravity), and the decreased porosity causes the increase in the cold strength. FIG. 24 suggest that the injection of diluted propane gas under a constant entering heat condition deceases the heat source in the sintering raw material particles, which allows the micropores of 500 μm or smaller originated from ore, affecting the reducing property, to easily remain, and allows producing the sintered ore having high reducing property.

[0105] FIG. 25 shows the schematic drawings of sintering behavior for the case that sole coke is used, (a) and the case that diluted gaseous fuel is simultaneously injected, (b). As seen in FIG. 25, the conventional sintering using only coke conducts heating from inside of pseudo-particles by the combustion of coke fine, while the simultaneous use of coke and gaseous fuel, in accordance with the method of the present invention, conducts heating from outside of the pseudo-particles by the combustion of gaseous fuel, which latter case presumably makes easily keep remaining the micropores in the ore, thus the JIS-RI also moves to relatively high position, though the RDI is at a low level.

[0106] FIG. 26 shows a schematic diagram of pore structure in the sintered ore under the injection of a diluted gaseous fuel. As shown in the diagram, it is effective for improving the productivity of sintered ore to enhance the joining of pores of 0.5 to 5 mm in size, which sizes affecting the yield and the cold strength, and to decrease the number of these pores, thus increasing the percentage of the pores of 5 mm or larger size, which sizes affecting the gas permeability. In addition, it is understood that the improvement in the reducing property of the sintered ore is attained preferably by forming a pore structure retaining a large quantity of micropores of 0.5 mm or smaller in size existing mainly in the iron ore. To this point, according to the present invention, injection of diluted gaseous fuel presumably attains a pore structure very close to that in the ideal sintered ore.

[0107] FIG. 27 shows the result of tests to grasp the limit coke ratio that can keep the necessary cold strength, (which limit coke ratio is a coke ratio equivalent to 73% of the shutter strength, which is the maximum value on not-using diluted propane gas). As shown in FIG. 27, the coke ratio to obtain the same cold strength to that of current state, (73% of shutter strength), by injecting diluted propane gas (0.5% by volume) can be decreased from 5% by mass to 3% by mass, (about 20 kg/t), as shown in FIG. 27 (a). Also as shown in FIG. 27 (b) and 27 (c), the coke ratio to attain 73% yield and 1.86 productivity decreases from 5% by mass to 3.5% by mass.

[0108] As described above, the present invention provides an action to strengthen the functions of combustion and melting zone in the sintering bed by charging a diluted gaseous fuel responding to the amount of carbonaceous material to an adequately selected position during the transition of the combustion and melting zone from surface layer to lower layer of the sintering bed accompanied with the travel of pallet, thereby improving the quality of sintered ore and increasing the productivity.

EXAMPLES

[0109]

(1) Example 1: Sintering pot test was conducted using the test pot shown in FIG. 6 and charging coke oven gas (C gas) as the diluted gaseous fuel (1 to 2.5% by volume), with the amount of carbonaceous material (coke) of 5% by mass in raw material. Other conditions were the same to those in the experiment described before. The result is given in FIG. 28. As seen in FIG. 28, when the C gas diluted in accordance with the method of the present invention was applied, increase in the concentration of C gas significantly widened the width of the combustion zone, further the yield and the productivity improved, and also the cold strength (SI) improved.

(2) Example 2: The test was conducted under the same conditions to those in Example 1. The result is given in FIG. 29. As shown in FIG. 29, when propane gas diluted in accordance with the method of the present invention, (0.02 to 0.5% by volume), was used, increase in the concentration of C gas significantly widened the width of the combustion zone, further the yield and the productivity improved, and also the cold strength (SI) improved.

(3) Example 3: The Example used the test pot shown in FIG. 6, and injected a coke oven gas (C gas) diluted by a cooler flue gas, as the comparison with the example of non-injection of diluted gas, from above the pot into the sintering bed of the sintering raw material (containing 20% by mass of return fine) given in TABLE 7.

In Example 3, the sintering layer contained 4.8 to 5.0% by mass (outside value) of coke fine. As an example compatible to the present invention, a C gas of 1.0 to 2.0% by volume (to air) was injected to a position of "100 to 400 mm" below the surface of the sintering bed (total thickness of 600 mm, containing 200 mm of return fine at the lowest layer), under a suction pressure of 1200 mmAq (1000 Aq of pressure difference). When the total length of the DL sintering machine was 80 m and when the length was applied to the total height of 600 mm, the injection point "100 to 200 mm" in Test No. 2 corresponded to an example that the sintering machine was operated with the installation of the diluted gas injection hood 12 having the length of 13.3 m at the position of [80 m x (100 to 200)/ 600 mm = 13.3 to 26.6 m]. Accordingly, the example of Test No. 2 with the injection position of "200 to 300 mm" corresponds to the case of diluted gas injection while the diluted gas injection hood 12 having 13.3 m in length is positioned at about 26.7 to 39.7 mm behind the ignition furnace on the sintering machine pallet.

TABLE 7

	Condition \ Test No.	1	2	3	4	5	6	7
Percentage of raw material (mass%)	Yandi (-8mm)	33.76	33.76	33.76	33.76	33.76	33.76	33.76
	Carajas (-8mm)	33.76	33.76	33.76	33.76	33.76	33.76	33.76
	Silica rock (-1mm)	2.24	2.24	2.24	2.24	2.24	2.24	2.24
	Calcium oxide	1.52	1.52	1.52	1.52	1.52	1.52	1.52
	Limestone (-3mm)	8.72	8.72	8.72	8.72	8.72	8.72	8.72
	Return fine	20.00	20.00	20.00	20.00	20.00	20.00	20.00
	Coke (-3mm)	(5.0)	(4.9)	(4.9)	(4.9)	(4.8)	(4.8)	(4.8)
Gas injection condition	Injection gas	None (Base)	C gas	C gas	C gas	C gas	C gas	C gas
	Concentration (vol% to Air)	-	1.0	1.0	1.0	2.0	2.0	2.0
	Charge position (basis: 0 mm at surface)	-	100-200mm	200-300mm	300-400mm	100-200mm	200-300mm	300-400mm
Bed height (mm)		400	400	400	400	400	400	400
Pressure difference (mmAq)		1000	1000	1000	1000	1000	1000	1000
Remark								

* The percentage of coke is outside value.

TABLE 8 shows the results of Example 3 (Nos. 1 to 7). As seen in the results, cold strength (SI strength) and yield of the sintered ore increased in No. 2 to No. 7 which are compatible examples to the present invention, compared with No. 1 which is a comparative example. In particular, examples Nos. 3, 4, 6, and 7 which positioned the injection point to an intermediate stage of the sintering bed showed significant improvement. Furthermore, it was found that the productivity increases by adjusting the injection gas concentration to 1% by volume under a condition of constant coke amount (4.8% by mass) rather than decreasing the coke amount and increasing the injection gas concentration. For the quality of sintered ore, it was found that the highest effect is attained by the injection at a position affecting the intermediate stage of the sintering bed at 200 to 300 mm for both the reducing property (RI) and the reduction degradation index (RDI).

TABLE 8

Result \ Test No.			1	2	3	4	5	6	7
Water content in raw material (%)			6.70	6.93	6.84	7.20	7.04	7.24	7.19
Charged wet amount (wet·kg)			12.7	12.7	12.7	12.7	12.7	13.0	13.0
Charged wet density (wet·ton/m^3)			1.80	1.80	1.80	1.80	1.80	1.84	1.84
Charged dry amount (dry·kg)			11.8	11.8	11.8	11.8	11.8	12.1	12.1
Charged dry density (dry·ton/m^3)			1.68	1.67	1.67	1.67	1.67	1.71	1.71
Gas pressure before ignition (mmH$_2$O)			981	981	974	979	995	978	963
Flue gas temperature (°C)			283	320	323	323	305	320	331
Fired amount (kg)			10.4	10.5	10.3	10.5	10.4	10.6	10.9
Production (kg)			7.5	7.6	7.3	7.3	7.3	7.5	7.7
SI strength (%)			68.9	70.3	73.1	72.9	69.3	74.1	73.8
Yield (%)			71.2	72.0	72.6	72.7	69.9	73.5	75.5
Sintering time (min)			15.9	15.9	14.6	14.9	14.8	15.9	16.3
Productivity (t/h/m^2)			1.59	1.61	1.74	1.73	1.67	1.71	1.68
Position (mm)	100-200	Ultimate maximum temperature (°C)	1250	1240	1240	1240	1230	1230	1230
		Holding time in high temperature zone (> 1200°C) (sec)	30	33	30	30	35	30	30
	200-300	Ultimate maximum temperature (°C)	1290	1280	1280	1280	1270	1270	1270
		Holding time in high temperature zone (> 1200°C) (sec)	45	45	60	45	45	80	45
	300-400	Ultimate maximum temperature (°C)	1360	1330	1330	1330	1320	1320	1320
		Holding time in high temperature zone (> 1200°C) (sec)	60	50	60	100	60	70	120
Reduction index (RI)			67.4	78.1	85.4	76.3	74.4	77.7	76.6
Reduction degradation index (RDI)			29.3	31.6	30.8	32.2	29.9	30.9	30.0
T. Fe (%)			59.5	59.0	59.7	59.6	59.7	59.7	59.6
FeO (%)			9.8	9.3	10.1	9.5	8.9	9.5	9.5

(4) Example 4: The Example describes an application of the method for producing sintered ore according to the present invention to a DL sintering machine of a scale of 10,000 t/d. The DL sintering machine had a length of 90 m between the ignition furnace and the ore-discharge opening. A gas injection hood having 15 m in length (in the pallet moving direction) to cover entire width of the machine was placed at about 30 m behind the ignition furnace of the sintering machine. The gaseous fuel adopted coke oven gas (C gas). Not particularity targeting the upper layer portion of the raw material sintering bed of the sintering machine, the C gas which was adjusted to 2% by volume concentration using normal temperature air was injected at a position equivalent to 300 mm apart from the position existing the combustion and melting zone which propagated to 200 mm equivalent position from the surface layer in the thickness direction of the sintering bed under a condition of 600 mm of sintering bed height (excluding 200 mm of return fine thickness) . The injected C gas was brought into combustion in the combustion and melting zone after reaching the above position through the sintering layer by adjusting the negative pressure of suction at the wind box below the sintering machine pallet. The internal pressure of the gas injection hood was regulated to slightly positive from the atmospheric pressure, thus kept balance with the suction negative pressure of the wind box. The use rate of C gas was 3,000 m^3 (standard state)/hr.

[0110] The operation of the sintering machine totally increased the tumbler strength by about 3% from that of the ordinary operation, improved the RDI by about 3% therefrom, improved RI by about 4% therefrom, and further improved the productivity by 0.03 $t/hr \cdot m^3$.

Claims

1. A method for producing sintered ore, comprising:

a charging step of charging a sintering raw material containing a fine iron ore and a carbonaceous material onto a pallet moving in circulation, thus forming a sintering bed containing the carbonaceous material on the pallet;
an igniting step of igniting the carbonaceous material on the surface of the sintering bed at an ignition furnace;
a sintering step of combusting the carbonaceous material in the sintering bed by sucking air through wind boxes positioned below the pallet, thus forming a sintered cake utilizing the generated combustion heat; and
a gaseous fuel combusting step of feeding a gaseous fuel, which is diluted to below the lower limit concentration of combustion, into the sintering bed from above the sintering bed, and combusting the gaseous fuel in the sintering bed.

2. The method for producing sintered ore according to claim 1, wherein the gaseous fuel combusting step comprising:

feeding a gaseous fuel, which is diluted to below the lower limit concentration of combustion, into the sintering bed from above the sintering bed, and combusting the gaseous fuel in the sintering bed; and
adjusting an ultimate maximum temperature in the sintering bed or a holding time in high temperature zone in the sintering bed, or an ultimate maximum temperature in the sintering bed and a holding time in high temperature zone in the sintering bed.

3. The method for producing sintered ore according to claim 2, wherein the gaseous fuel combusting step comprising:

feeding a gaseous fuel, which is diluted to below the lower limit concentration of combustion, into the sintering bed from above the sintering bed, and combusting the gaseous fuel in the sintering bed; and
adjusting an ultimate maximum temperature in the sintering bed.

4. The method for producing sintered ore according to claim 3, wherein the gaseous fuel combusting step comprising:

feeding a gaseous fuel, which is diluted to below the lower limit concentration of combustion, into the sintering bed from above the sintering bed, and combusting the gaseous fuel in the sintering bed; and
adjusting the ultimate maximum temperature in the sintering bed by adjusting an amount of the carbonaceous material in the sintering raw material.

5. The method for producing sintered ore according to claim 4, wherein the gaseous fuel combusting step comprising:

feeding a gaseous fuel, which is diluted to below the lower limit concentration of combustion, into the sintering bed from above the sintering bed, and combusting the gaseous fuel in the sintering bed; and adjusting the ultimate maximum temperature in the sintering bed to a temperature of from 1205°C to 1350°C by adjusting an amount of the carbonaceous material in the sintering raw material.

6. The method for producing sintered ore according to claim 3, wherein the gaseous fuel combusting step comprising:

feeding a gaseous fuel, which is diluted to below the lower limit concentration of combustion, into the sintering bed from above the sintering bed, and combusting the gaseous fuel in the sintering bed; and
adjusting an ultimate maximum temperature in the sintering bed to a temperature of from 1205°C to 1350°C by adjusting an amount of the gaseous fuel.

7. The method for producing sintered ore according to claim 3, wherein the gaseous fuel combusting step comprising:

feeding a gaseous fuel, which is diluted to below the lower limit concentration of combustion, into the sintering bed from above the sintering bed, and combusting the gaseous fuel in the sintering bed; and
adjusting an ultimate maximum temperature in the sintering bed to a temperature of from 1205°C to 1350°C by adjusting an amount of the carbonaceous material in the sintering raw material and an amount of the gaseous fuel.

8. The method for producing sintered ore according to claim 2, wherein the gaseous fuel combusting step comprising:

feeding a gaseous fuel, which is diluted to below the lower limit concentration of combustion, into the sintering bed from above the sintering bed, and combusting the gaseous fuel in the sintering bed; and
adjusting the holding time in the high temperature zone in the sintering bed.

9. The method for producing sintered ore according to claim 8, wherein the gaseous fuel combusting step comprising:

feeding a gaseous fuel, which is diluted to below the lower limit concentration of combustion, into the sintering bed from above the sintering bed, and combusting the gaseous fuel in the sintering bed; and
adjusting the holding time in the high temperature zone in the sintering bed by adjusting a concentration of the gaseous fuel responding to an amount of the carbonaceous material in the sintering raw material.

10. The method for producing sintered ore according to claim 1, wherein the gaseous fuel combusting step comprising:

feeding a gaseous fuel, which is diluted to below the lower limit concentration of combustion, into the sintering bed from above the sintering bed; and
combusting the gaseous fuel which is diluted to below the lower limit concentration of combustion so as at least a portion of the gaseous fuel to be left unburned until reaching the combustion and melting zone in the sintering bed.

11. The method for producing sintered ore according to claim 1, wherein the gaseous fuel combusting step comprising:

feeding a gaseous fuel, which is diluted to below the lower limit concentration of combustion, into the sintering bed from above the sintering bed; and
combusting the gaseous fuel in the sintering bed to adjust a shape of a combustion and melting zone.

12. The method for producing sintered ore according to claim 11, wherein the adjustment of the shape of the combustion and melting zone is carried out by adjusting a thickness of the combustion and melting zone in the height direction and/or by adjusting a width of the combustion and melting zone in the pallet moving direction.

13. The method for producing sintered ore according to claim 1, wherein the gaseous fuel combusting step comprising:

feeding the gaseous fuel which is diluted to below the lower limit concentration of combustion from above the sintering bed, thereby combusting the gaseous fuel in the sintering bed;
and
extending a holding time in high temperature zone in the combustion and melting zone to adjust cold strength of sintered ore.

14. The method for producing sintered ore according to claim 1, wherein the gaseous fuel combusting step comprising:

feeding the gaseous fuel which is diluted to below the lower limit concentration of combustion from above the sintering bed, thereby combusting the gaseous fuel in the sintering bed;
and
adjusting a feed position of the gaseous fuel to the sintering bed.

15. The method for producing sintered ore according to claim 1, wherein the gaseous fuel combusting step comprising:

feeding the gaseous fuel which is diluted to below the lower limit concentration of combustion from above the sintering bed at a position after the ignition furnace, thereby combusting the gaseous fuel in the sintering bed.

16. The method for producing sintered ore according to claim 1, wherein the gaseous fuel combusting step comprising:

feeding the gaseous fuel which is diluted to below the lower limit concentration of combustion after forming the sintered cake in the surface layer portion in the sintering bed and before a completion of the sintering, thereby combusting the gaseous fuel in the sintering bed.

17. The method for producing sintered ore according to claim 1, wherein the gaseous fuel combusting step comprising:

feeding the gaseous fuel which is diluted to below the lower limit concentration of combustion to a region which a thickness of a combustion and melting zone is 15 mm or more, thereby combusting the gaseous fuel in the sintering bed.

18. The method for producing sintered ore according to claim 1, wherein the gaseous fuel combusting step comprising:

feeding the gaseous fuel which is diluted to below the lower limit concentration of combustion at a position that the combustion front reaches 100 mm or deeper under the surface layer, thereby combusting the gaseous fuel in the sintering bed.

19. The method for producing sintered ore according to claim 1, wherein the gaseous fuel combusting step comprising:

feeding the gaseous fuel which is diluted to below the lower limit concentration of combustion to near both side walls of the sintering bed, thereby combusting the gaseous fuel in the sintering bed.

20. The method for producing sintered ore according to claim 1, wherein the gaseous fuel combusting step comprising:

feeding the gaseous fuel which is diluted to below the lower limit concentration of combustion from above the sintering bed in the longitudinal direction of the sintering machine, thereby combusting the gaseous fuel in the sintering bed; and
adjusting a cold strength of the sintered ore.

21. The method for producing sintered ore according to claim 1, wherein the gaseous fuel is a flammable gas which is diluted to a concentration of 75% or less and 2% or more of the lower limit concentration of combustion.

22. The method for producing sintered ore according to claim 10, wherein the gaseous fuel is a flammable gas which is diluted to a concentration of 60% or less and 2% or more of the lower limit concentration of combustion.

23. The method for producing sintered ore according to claim 11, wherein the gaseous fuel is a flammable gas which is diluted to a concentration of 25% or less and 2% or more of the lower limit concentration of combustion.

24. The method for producing sintered ore according to claim 1, wherein the gaseous fuel is one or more of gas selected from the group consisting of blast furnace gas, coke oven gas, a mixed gas of blast furnace gas and coke oven gas, propane gas, natural gas, and methane gas.

25. A sintering machine comprising pallets moving in circulation, suction wind boxes located below the pallet, a raw material charge apparatus for charging a sintering raw material onto the pallets, and an ignition furnace for igniting a carbonaceous material in the sintering raw material,
characterized in that a gaseous fuel feed apparatus is arranged at downstream side of the ignition furnace to inject a gaseous fuel which is diluted to below the lower limit concentration of combustion into the sintering bed from above

thereof.

26. The sintering machine according to claim 25, wherein the gaseous fuel feed apparatus is arranged at least one at downstream side of the ignition furnace in the longitudinal direction of the sintering machine.

27. The sintering machine according to claim 25, wherein the gaseous fuel feed apparatus is arranged at a position between a stage that the combustion front propagates below the surface layer in the pallet moving direction and a stage of completion of the sintering.

28. The sintering machine according to claim 24, wherein the gaseous fuel feed apparatus is arranged near a side wall.

29. The sintering machine according to claim 25, wherein the gaseous fuel feed apparatus feeds a flammable gas which is diluted to a concentration of 75% or less and 2% or more of the lower limit concentration of combustion.

30. The sintering machine according to claim 29, wherein the gaseous fuel feed apparatus feeds a flammable gas which is diluted to a concentration of 60% or less and 2% or more of the lower limit concentration of combustion.

31. The sintering machine according to claim 30, wherein the gaseous fuel feed apparatus feeds a flammable gas which is diluted to a concentration of 25% or less and 2% or more of the lower limit concentration of combustion.

FIG. 1

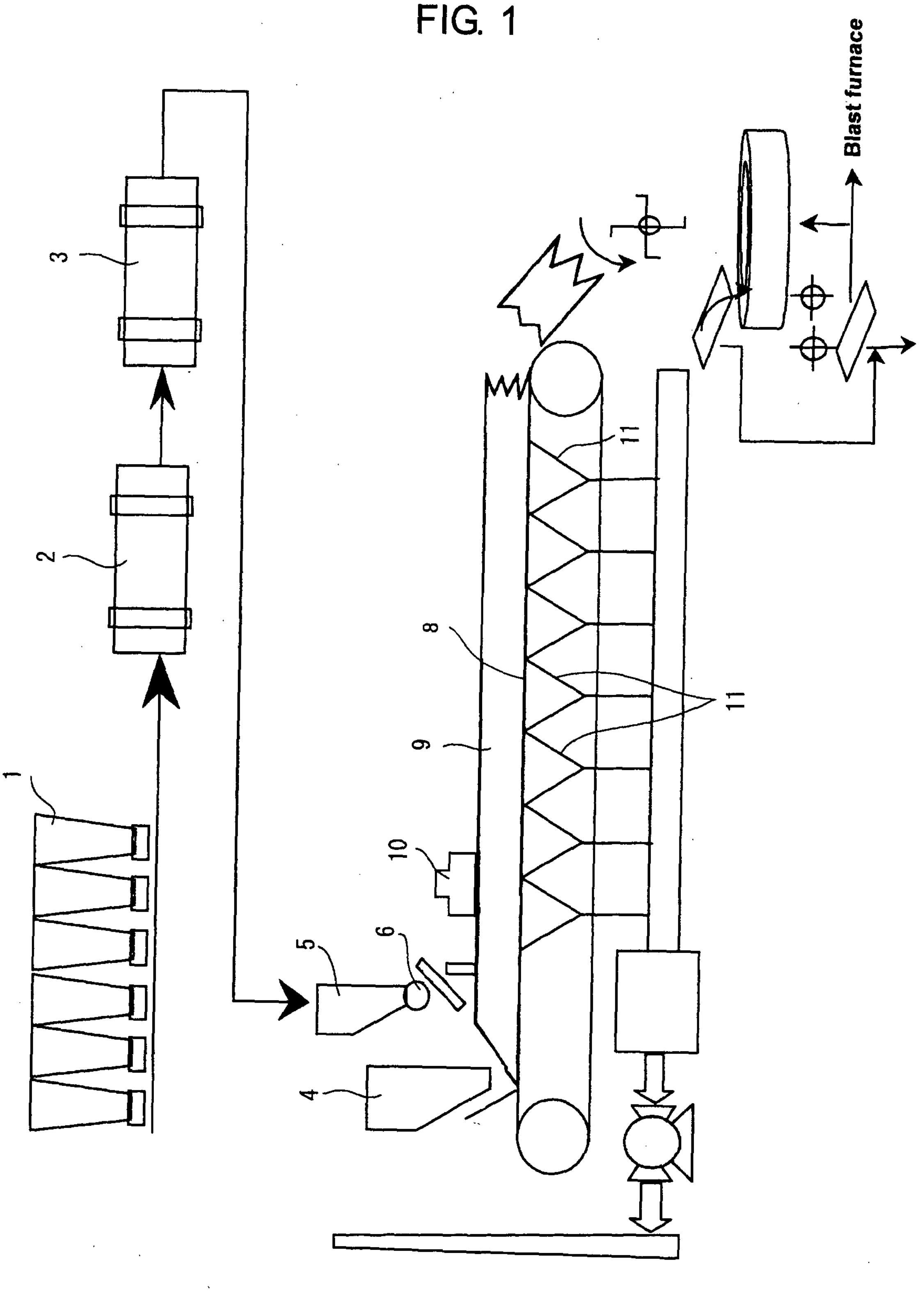


FIG. 2

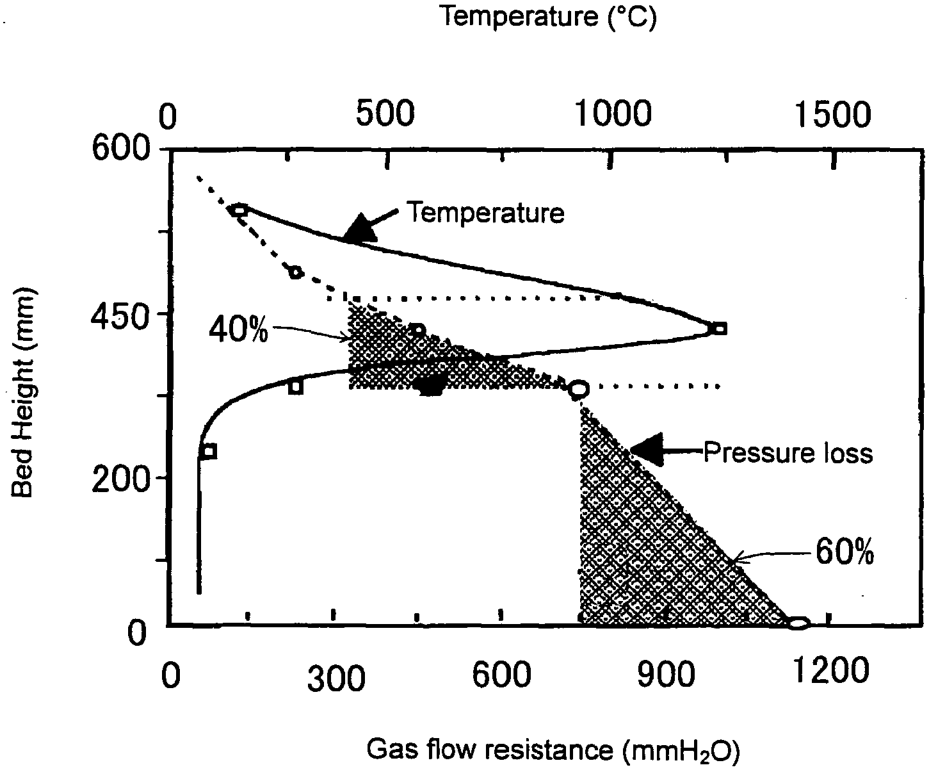

Temperature (°C)
0
500
1000
1500
600
450
200
0
Bed Height (mm)
Temperature
40%
Pressure loss
60%
0
300
600
900
1200
Gas flow resistance (mmH2O)

FIG. 3

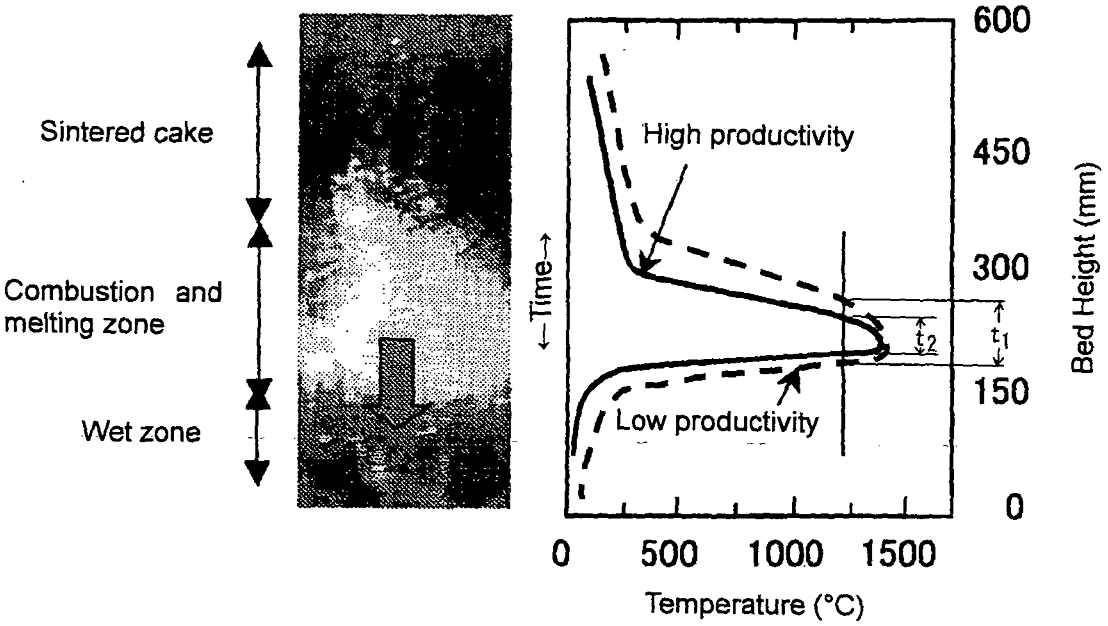

Sintered cake
Combustion and melting zone
Wet zone
←Time→
High productivity
Low productivity
t_2
t_1
600
450
300
150
0
Bed Height (mm)
0
500
1000
1500
Temperature (°C)

FIG. 4

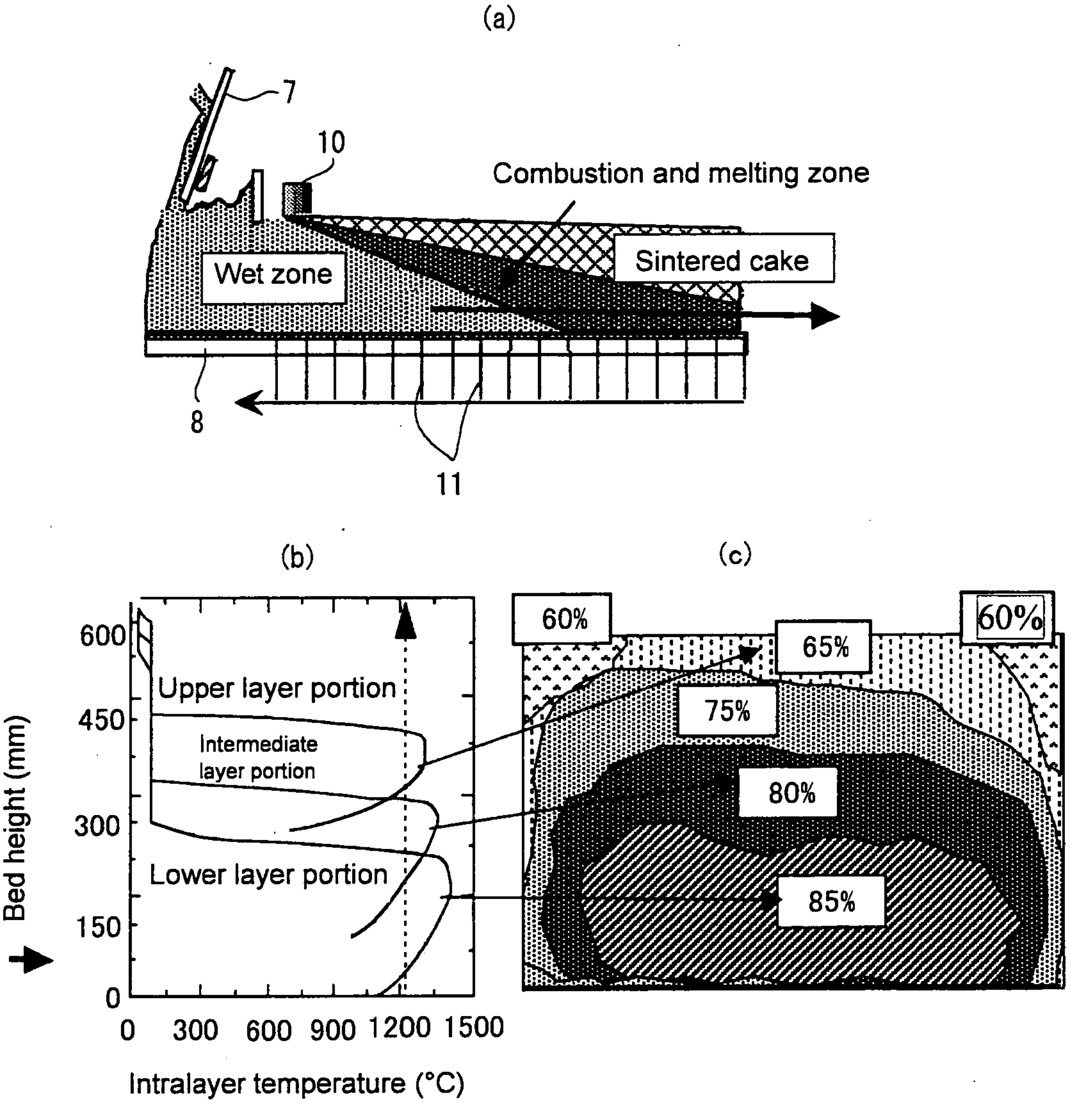

(a)
7
10
Combustion and melting zone
Wet zone
Sintered cake
8
11
(b)
(c)
600
450
300
150
0
Bed height (mm)
Upper layer portion
Intermediate layer portion
Lower layer portion
0
300
600
900
1200
1500
Intralayer temperature (°C)
60%
65%
60%
75%
80%
85%

FIG. 5

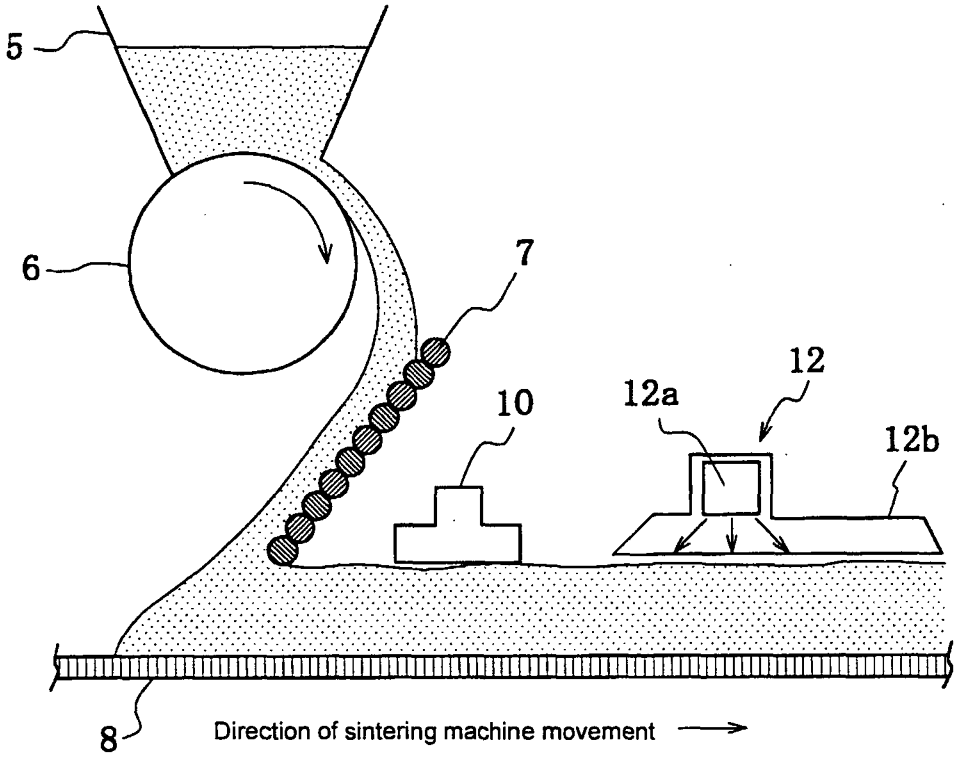


FIG. 6

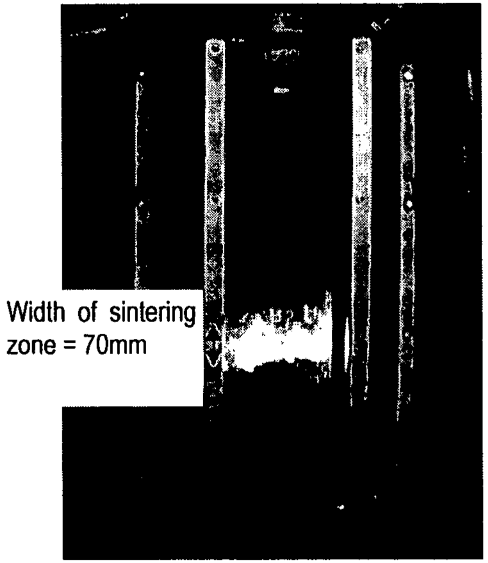
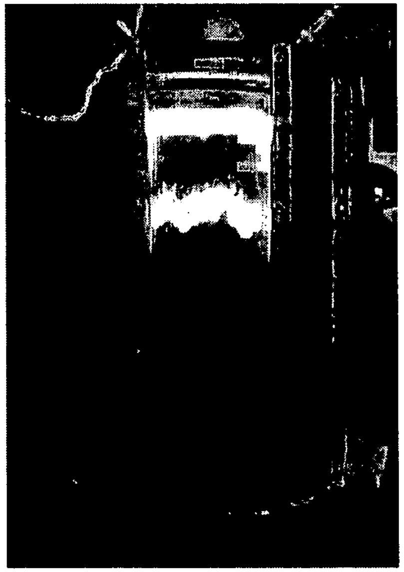
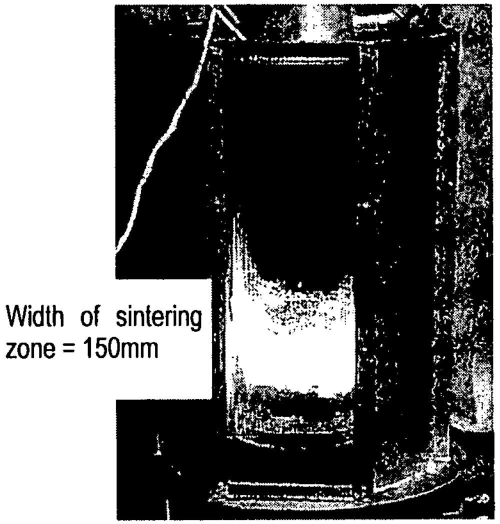
1) Sintering in air	2) M gas injection (15vol%)	3) M gas injection (3vol%)
		
	M gas combusts on the surface immediately after the injection.	Width of the combustion zone widens.

FIG. 7

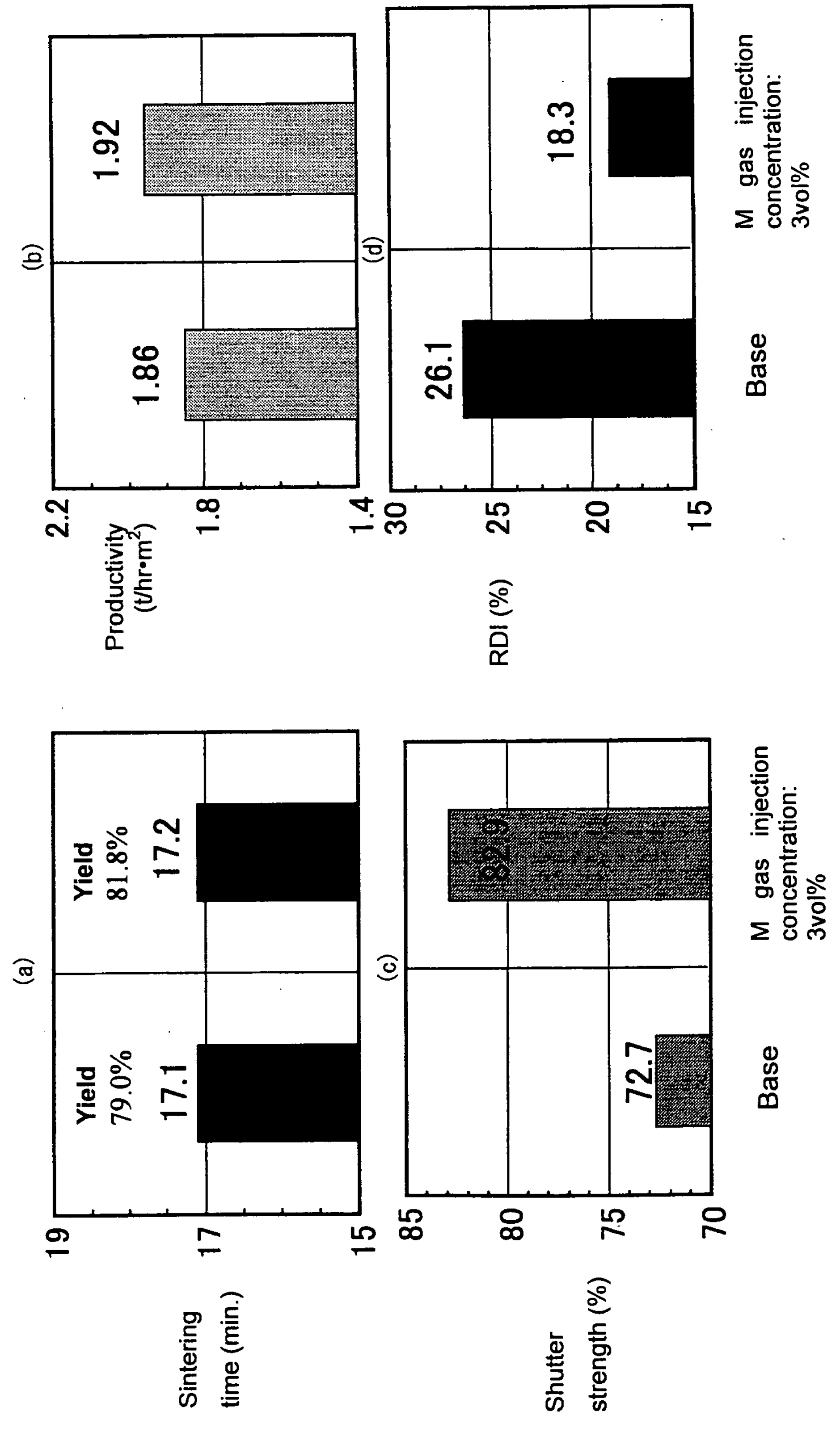

(a)
Sintering time (min.)
19
17
15
Yield 79.0%
17.1
Yield 81.8%
17.2
(b)
Productivity (t/hr·m2)
2.2
1.8
1.4
1.86
1.92
(c)
Shutter strength (%)
85
80
75
70
72.7
82.9
(d)
RDI (%)
30
25
20
15
26.1
18.3
Base
M gas injection concentration: 3vol%
Base
M gas injection concentration: 3vol%

FIG. 8

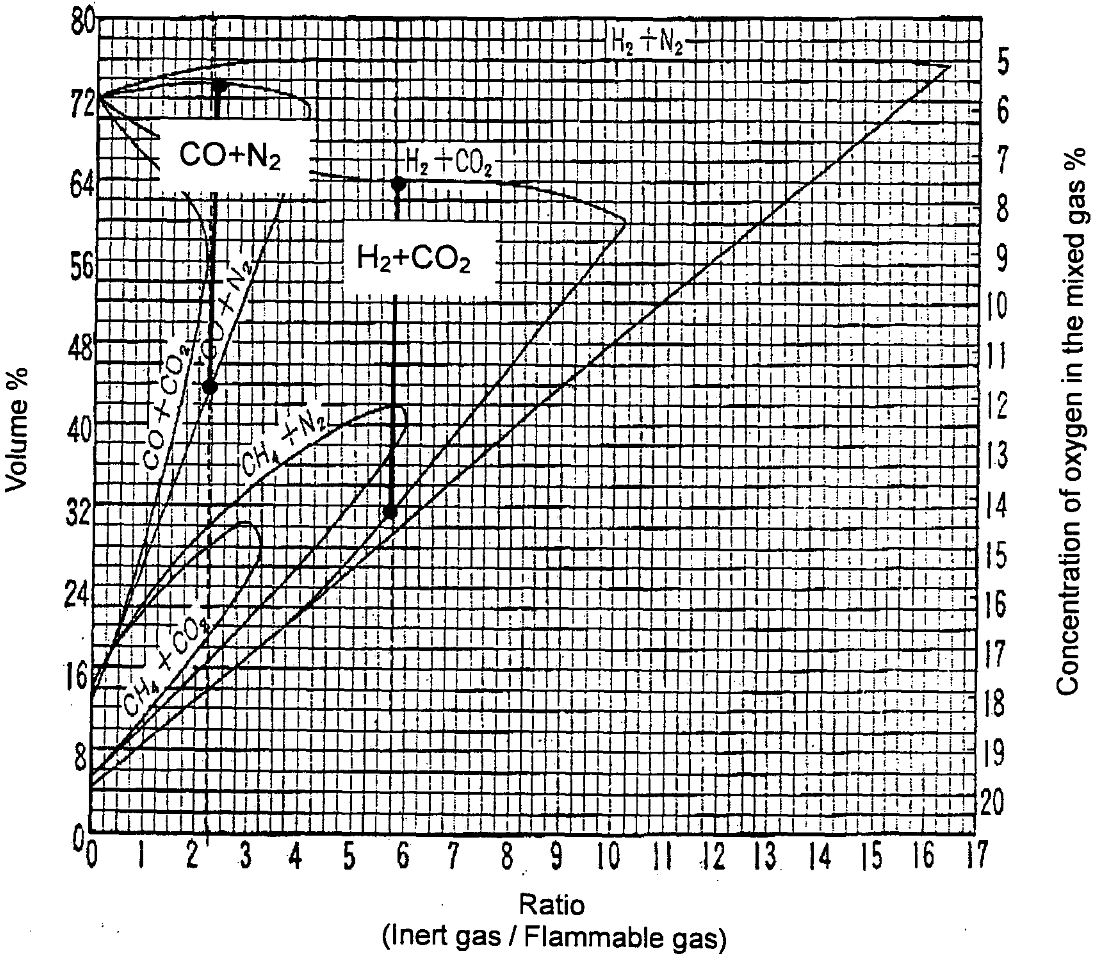
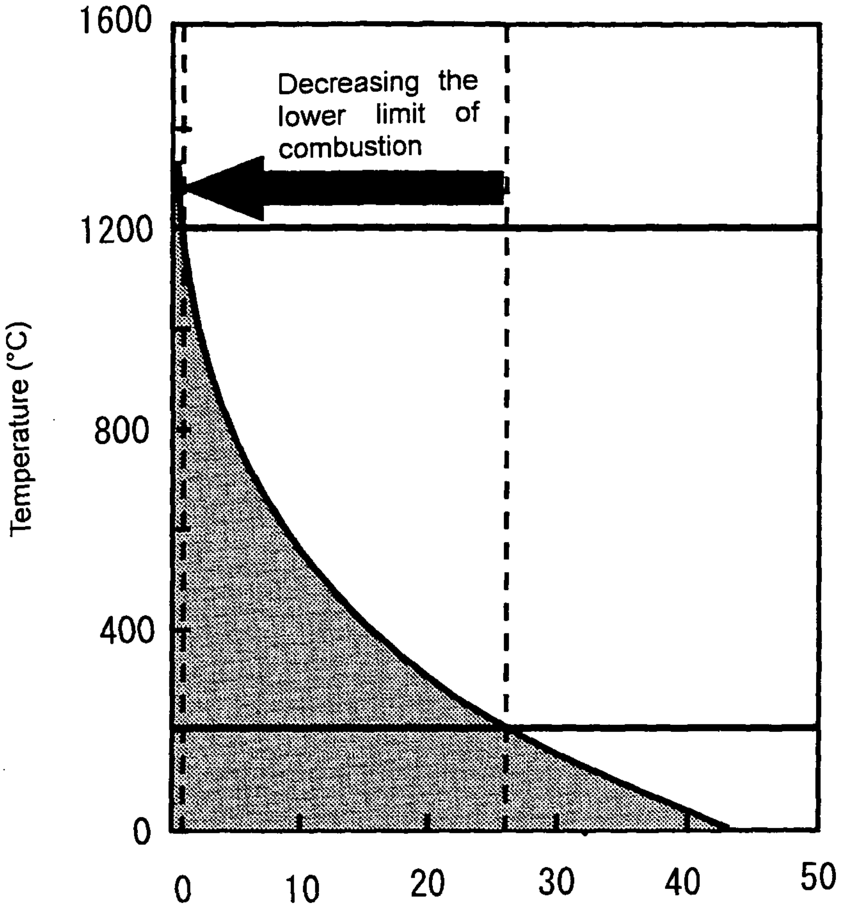

Volume %
80
72
64
56
48
40
32
24
16
8
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Ratio
(Inert gas / Flammable gas)
Concentration of oxygen in the mixed gas %
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
H_2+N_2
H_2+CO_2
CO+N₂
H₂+CO₂
$CO+CO_2$
$CO+N_2$
CH_4+N_2
CH_4+CO_2

FIG. 9



Concentration of combustion gas (vol%)
* Cited from "Combustion Handbook",
CORONA PUBLISHING CO., LTD.

FIG. 10

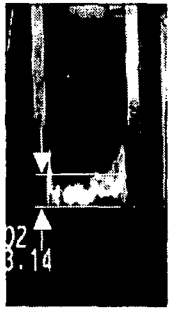
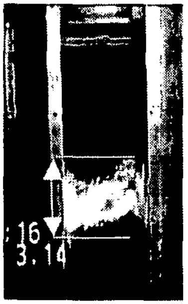
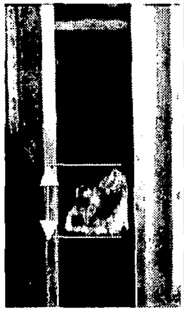
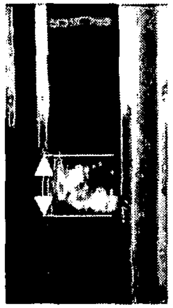
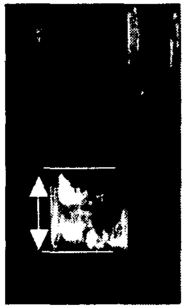
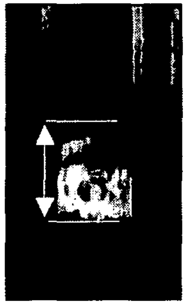
Kind of injection gas	Conventional sintering	Propane gas	H_2 gas	CO gas	Methane gas	C gas	LNG
Concentration (vol%, to Air)	—	0.4	3.0	2.4	0.9	2.0	0.8
Coke fine (mass%)	5.0	4.2	4.2	4.2	4.2	4.2	4.2
Molecular weight	—	44	2	28	16	8.6	18.4
Average ignition temperature (°C)	—	568	585	666	700	about 630	about 670
Shutter strength (%)	67.7	75.5	76.0	74.1	74.5	75.4	75.5
Yield (%)	69.0	72.8	74.6	73.4	73.9	74.6	75.9
Sintering time (min)	16.0	16.7	17.1	18.6	18.8	17.3	18.3
Productivity (t/hr•m²)	1.56	1.64	1.63	1.58	1.55	1.64	1.65
State of combustion							

FIG. 11

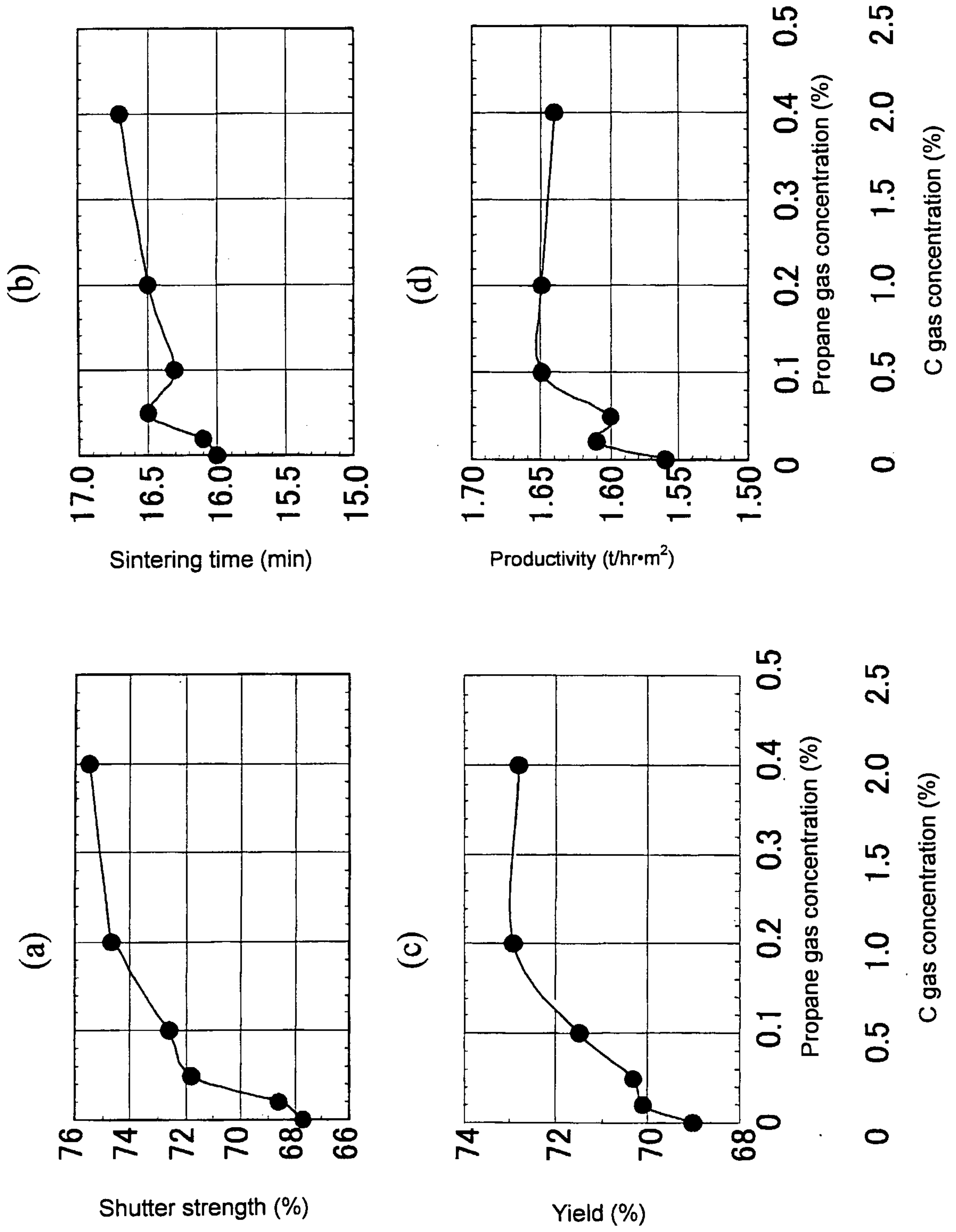

(a)
Shutter strength (%)
76
74
72
70
68
66
(b)
Sintering time (min)
17.0
16.5
16.0
15.5
15.0
(c)
Yield (%)
74
72
70
68
(d)
Productivity (t/hr•m^2)
1.70
1.65
1.60
1.55
1.50
0
0.1
0.2
0.3
0.4
0.5
Propane gas concentration (%)
0
0.5
1.0
1.5
2.0
2.5
C gas concentration (%)

FIG. 12

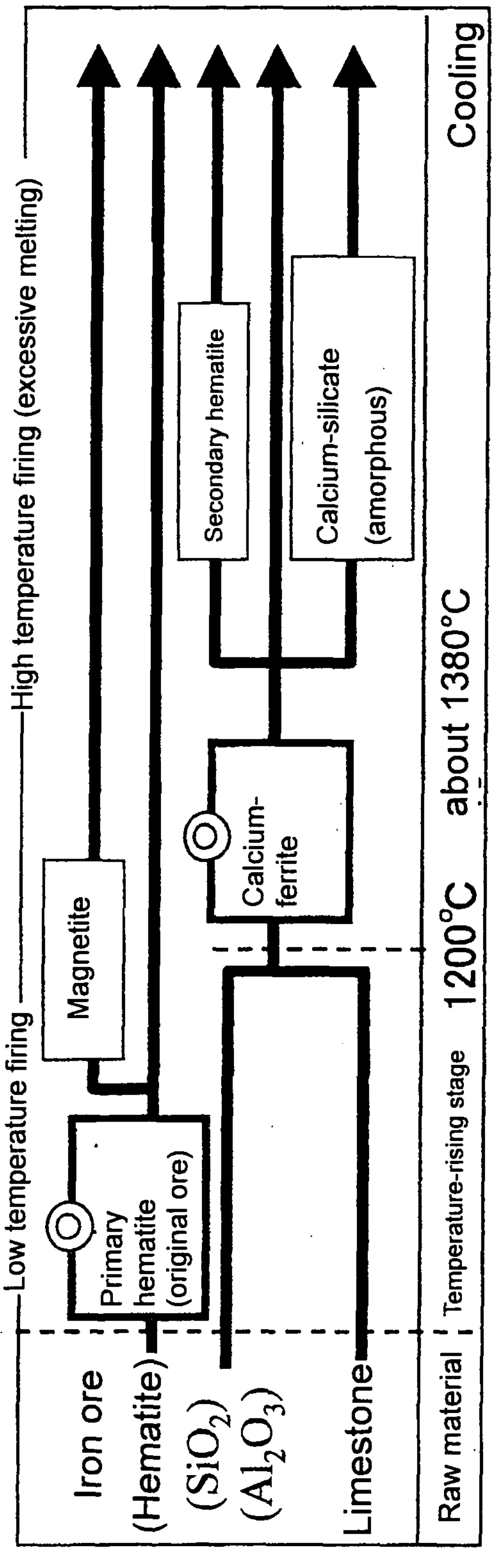

Iron ore
(Hematite)
(SiO_2)
(Al_2O_3)
Limestone
Raw material
Temperature-rising stage
1200°C
about 1380°C
Cooling
Low temperature firing
High temperature firing (excessive melting)
◎ Primary hematite (original ore)
Magnetite
◎ Calcium-ferrite
Secondary hematite
Calcium-silicate (amorphous)

FIG. 13

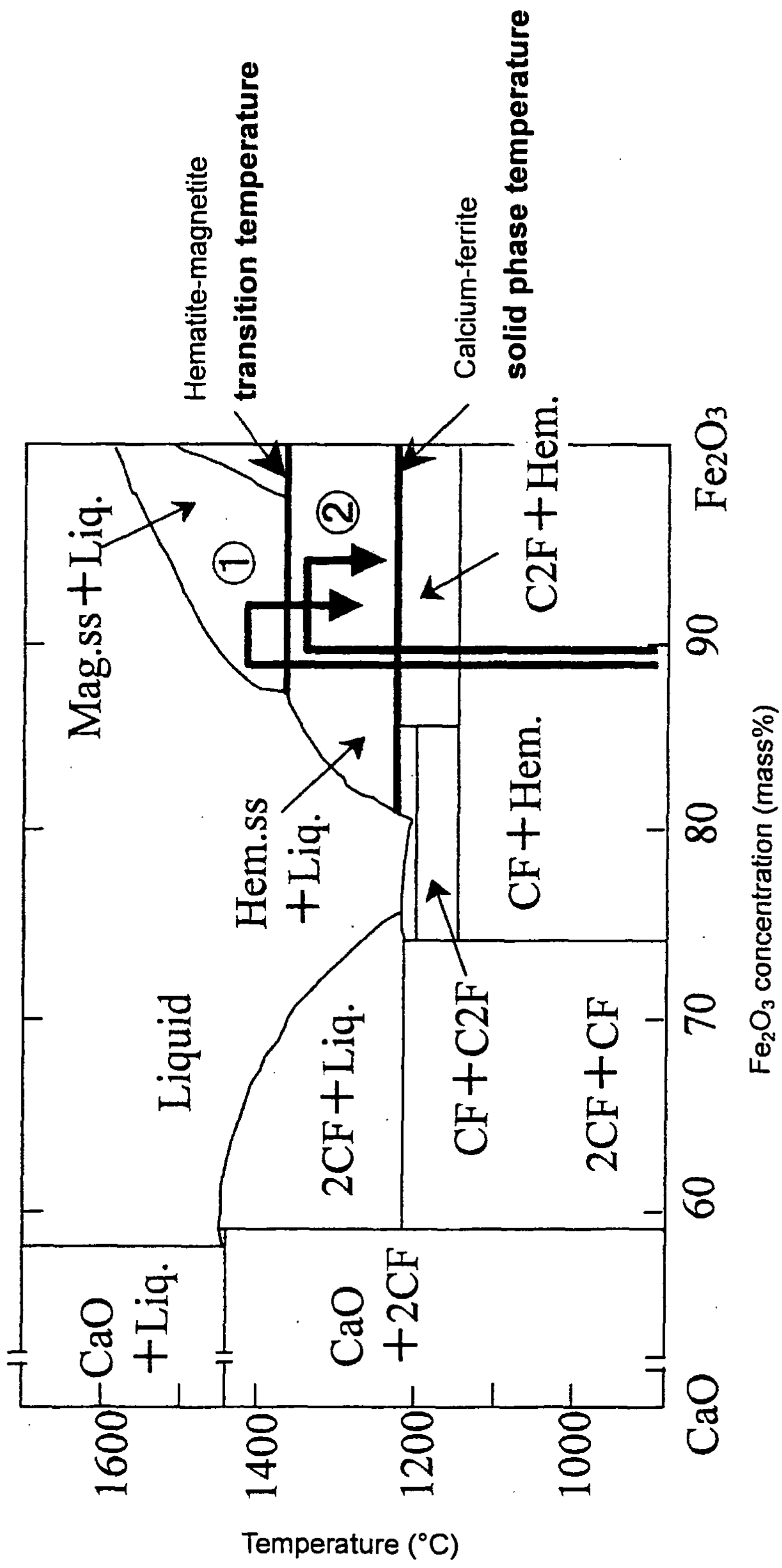

Hematite-magnetite
transition temperature
Calcium-ferrite
solid phase temperature
Mag.ss+Liq.
①
②
C2F+Hem.
Hem.ss
+Liq.
CF+Hem.
Liquid
2CF+Liq.
CF+C2F
2CF+CF
CaO
+Liq.
CaO
+2CF
1600
1400
1200
1000
Temperature (°C)
CaO
60
70
80
90
Fe_2O_3
Fe_2O_3 concentration (mass%)

FIG. 14

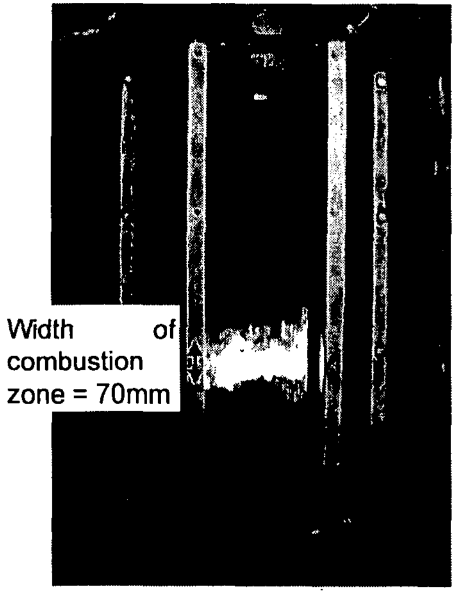
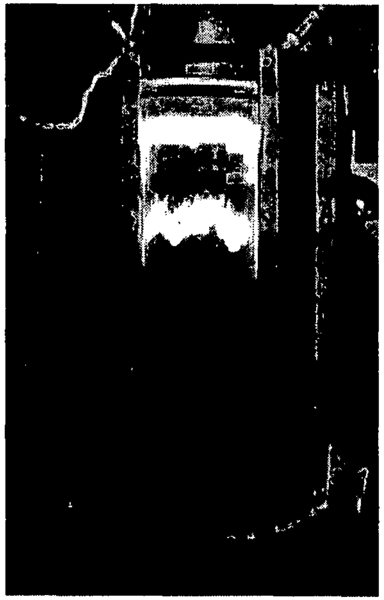
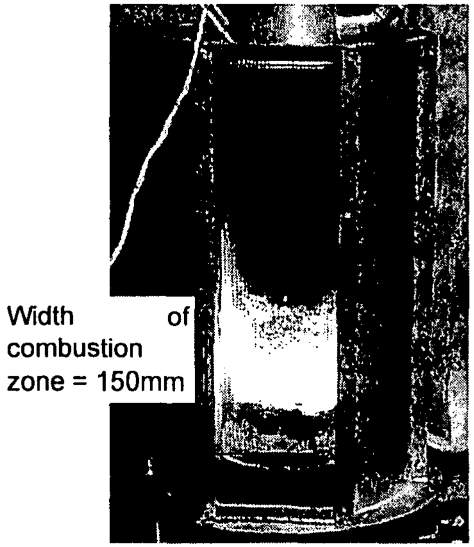
1) Sole coke fine	2) Injection of propane gas (2.5 vol% of concentration)	3) Injection of propane gas (0.5 vol% of concentration)
		
The width of combustion and melting zone is narrow.	Propane gas combusts on the surface immediately after the injection.	The width of combustion and melting zone widens.

FIG. 15

Injection position (mm)	(Conventional method) None	100～200	200～300	300～400
2nd layer from the surface of four segments (100 to 200 mm)				
3rd layer from the surface of four segments (200 to 300 mm)				
4th layer from the surface of four segments (300 to 400 mm)				

FIG. 16

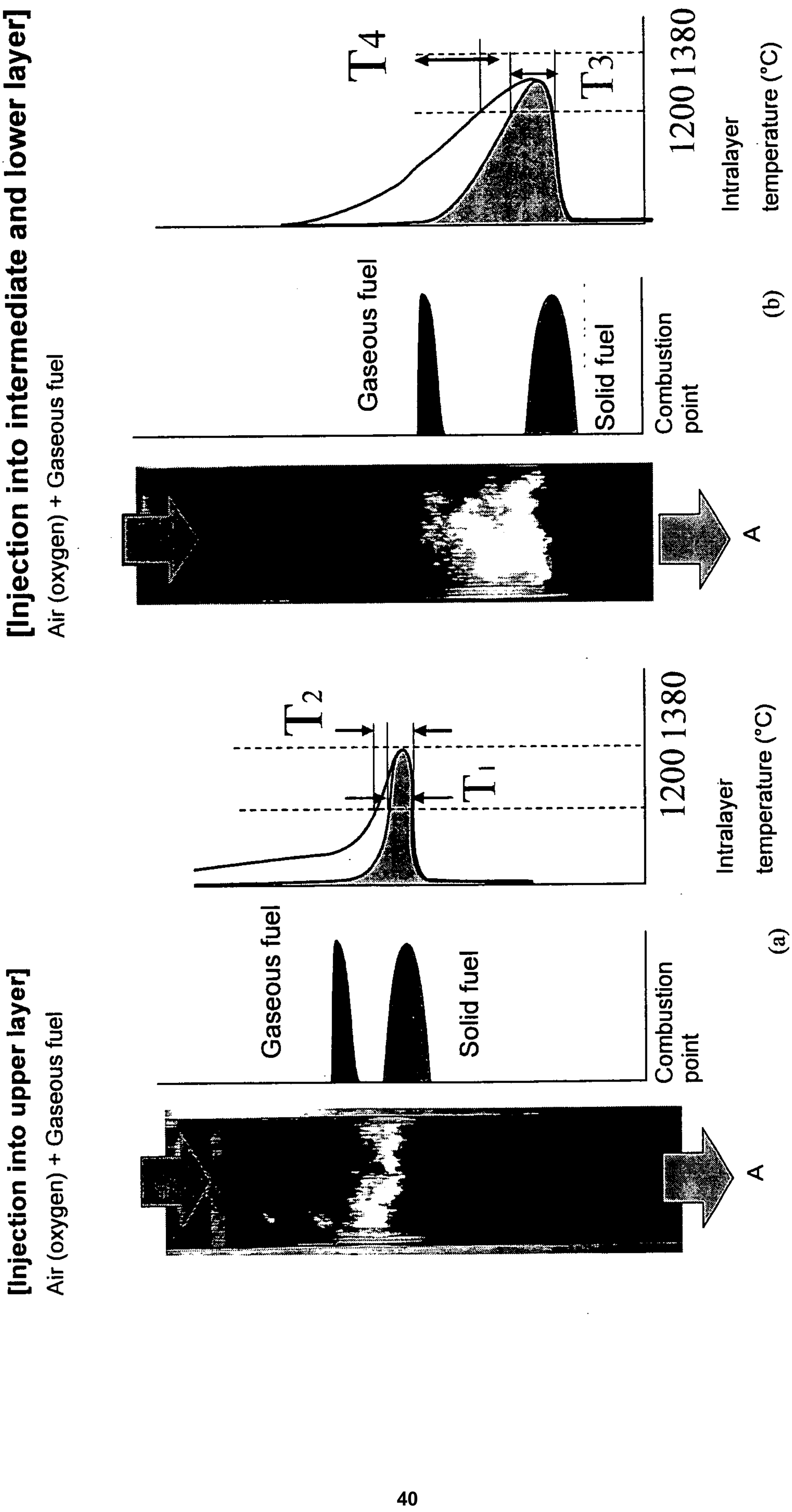

[Injection into upper layer]
Air (oxygen) + Gaseous fuel
A
Gaseous fuel
Solid fuel
Combustion point
(a)
T2
T1
1200 1380
Intralayer temperature (°C)
[Injection into intermediate and lower layer]
Air (oxygen) + Gaseous fuel
A
Gaseous fuel
Solid fuel
Combustion point
(b)
T4
T3
1200 1380
Intralayer temperature (°C)

FIG. 17

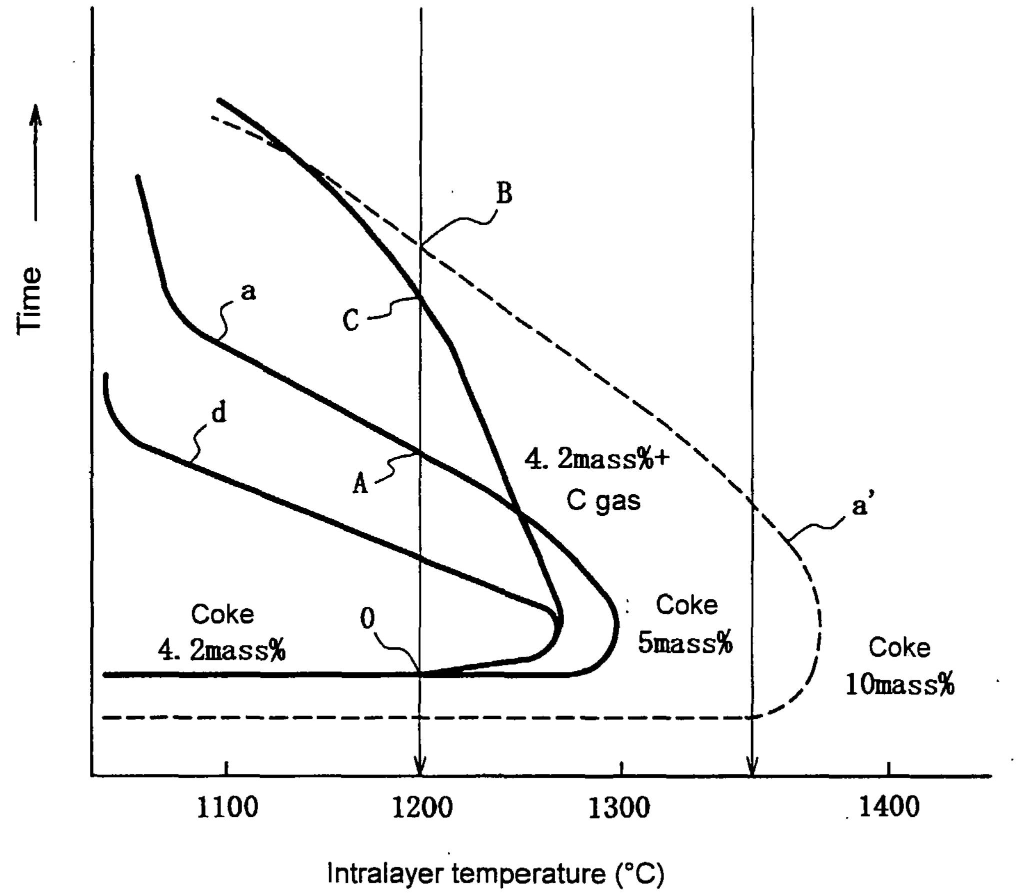

Time
B
a
C
d
A
4. 2mass%+
C gas
a'
Coke
4. 2mass%
0
Coke
5mass%
Coke
10mass%
1100
1200
1300
1400
Intralayer temperature (°C)

FIG. 18

	Conventional sintering method		Example compatible to the present invention			
Injection gas concentration	None		C gas: 2.0			
Quantity of coke (mass%)	5.0		4.2			
Injection position	—		Injection to entire layer (400 mm)		Injection to lower layer 1/2 (200 mm)	
Dry method	Video	Thermobia	Video	Thermobia	Video	Thermobia
Combustion state at upper layer portion						
Combustion state at lower layer portion						

FIG. 19

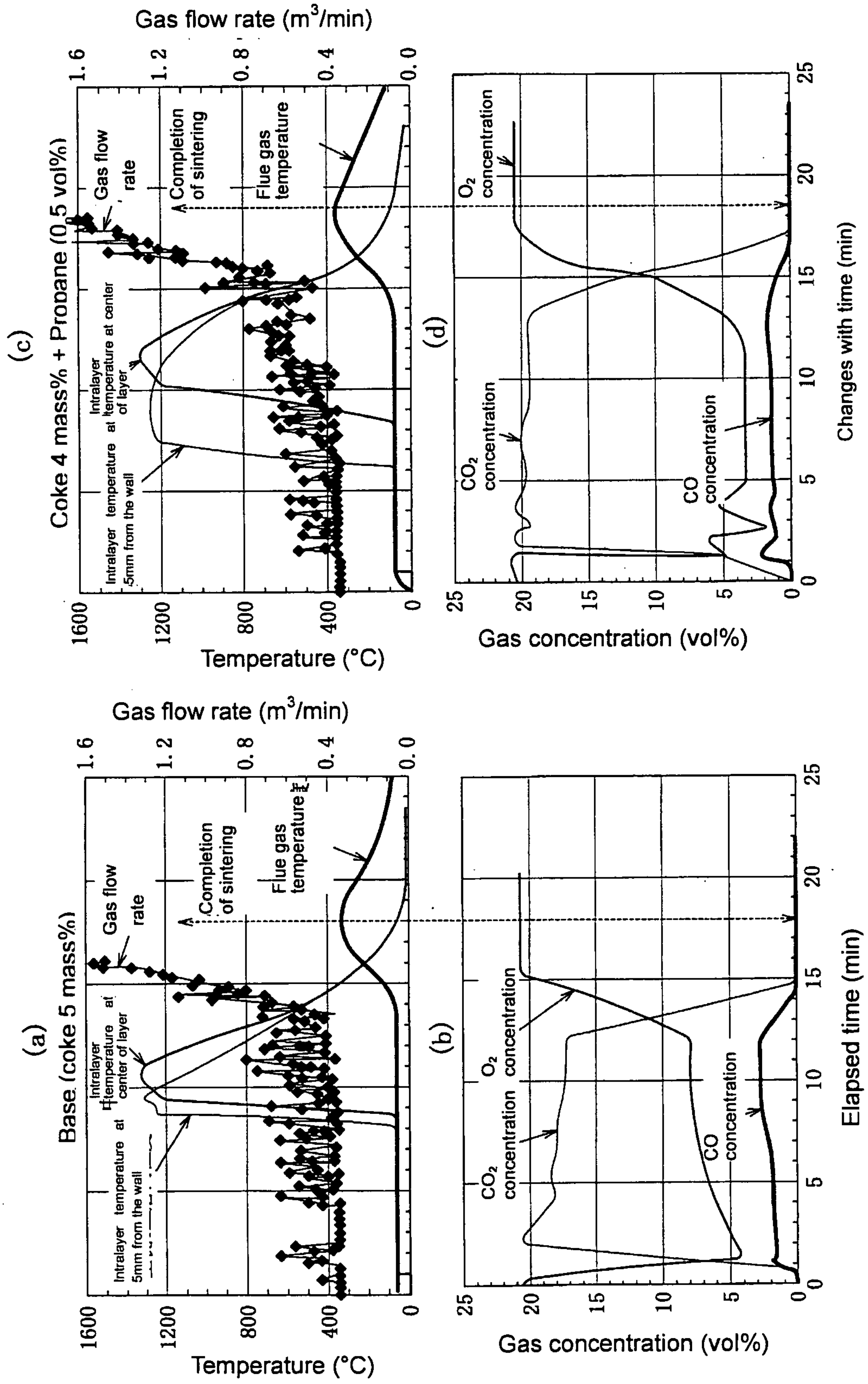

(c)
Coke 4 mass% + Propane (0.5 vol%)
Gas flow rate (m³/min)
1.6
1.2
0.8
0.4
0.0
Gas flow rate
Completion of sintering
Flue gas temperature
Intralayer temperature at center of layer
Intralayer temperature 5mm from the wall
1600
1200
800
400
0
Temperature (°C)
(d)
O₂ concentration
CO₂ concentration
CO concentration
25
20
15
10
5
0
Gas concentration (vol%)
0
5
10
15
20
25
Changes with time (min)
(a)
Base (coke 5 mass%)
Gas flow rate (m³/min)
1.6
1.2
0.8
0.4
0.0
Gas flow rate
Completion of sintering
Flue gas temperature
Intralayer temperature at center of layer
Intralayer temperature at 5mm from the wall
1600
1200
800
400
0
Temperature (°C)
(b)
O₂ concentration
CO₂ concentration
CO concentration
25
20
15
10
5
0
Gas concentration (vol%)
0
5
10
15
20
25
Elapsed time (min)

FIG. 20

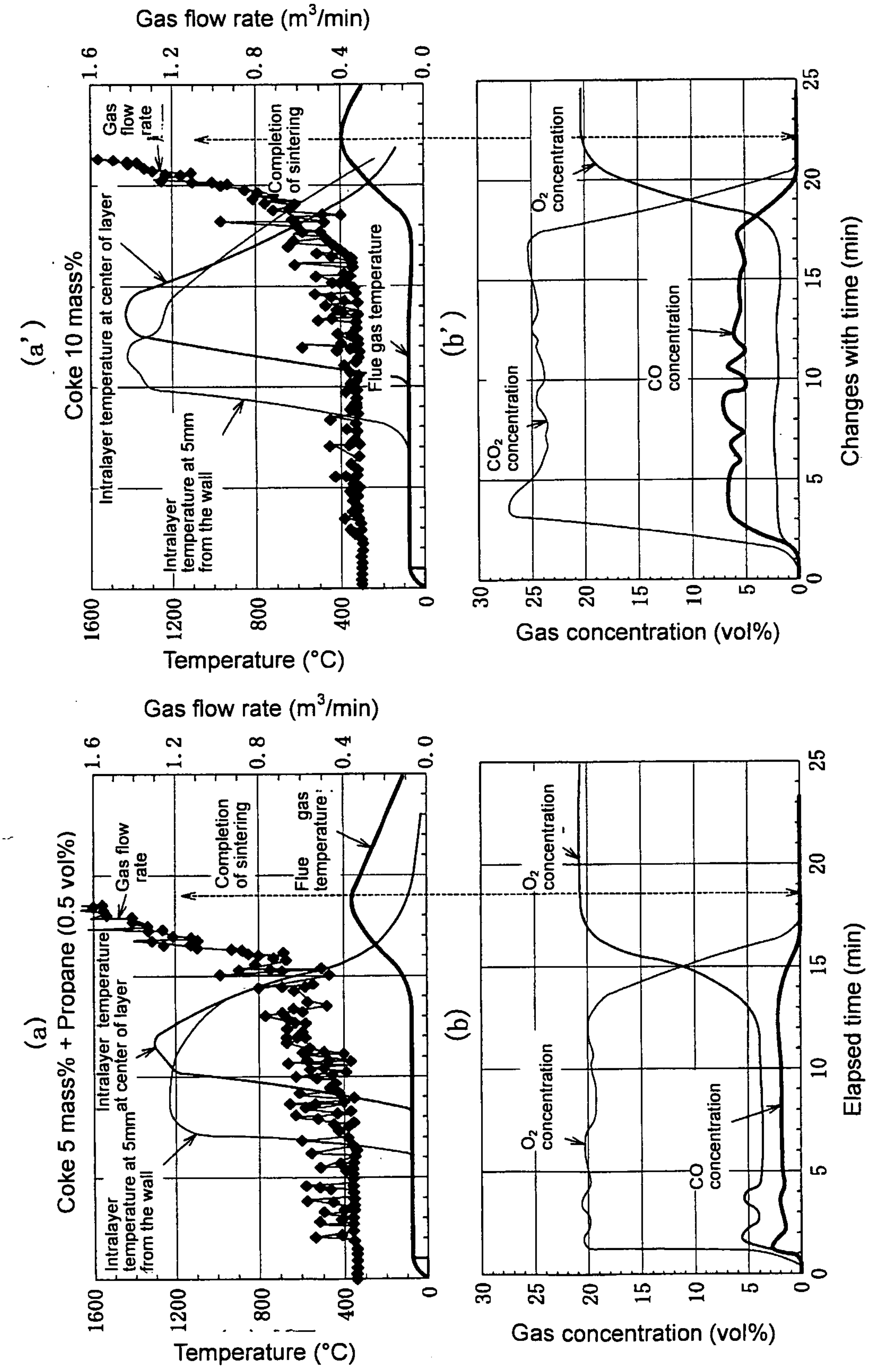

(a')
Coke 10 mass%
Gas flow rate (m³/min)
1.6
1.2
0.8
0.4
0.0
Gas flow rate
Completion of sintering
Intralayer temperature at center of layer
Intralayer temperature at 5mm from the wall
Flue gas temperature
1600
1200
800
400
0
Temperature (°C)
(b')
O₂ concentration
CO₂ concentration
CO concentration
30
25
20
15
10
5
0
Gas concentration (vol%)
0
5
10
15
20
25
Changes with time (min)
(a)
Coke 5 mass% + Propane (0.5 vol%)
Gas flow rate (m³/min)
1.6
1.2
0.8
0.4
0.0
Gas flow rate
Completion of sintering
Flue gas temperature
Intralayer temperature at center of layer
Intralayer temperature at 5mm from the wall
1600
1200
800
400
0
Temperature (°C)
(b)
O₂ concentration
O₂ concentration
CO concentration
CO concentration
30
25
20
15
10
5
0
Gas concentration (vol%)
0
5
10
15
20
25
Elapsed time (min)

FIG. 21

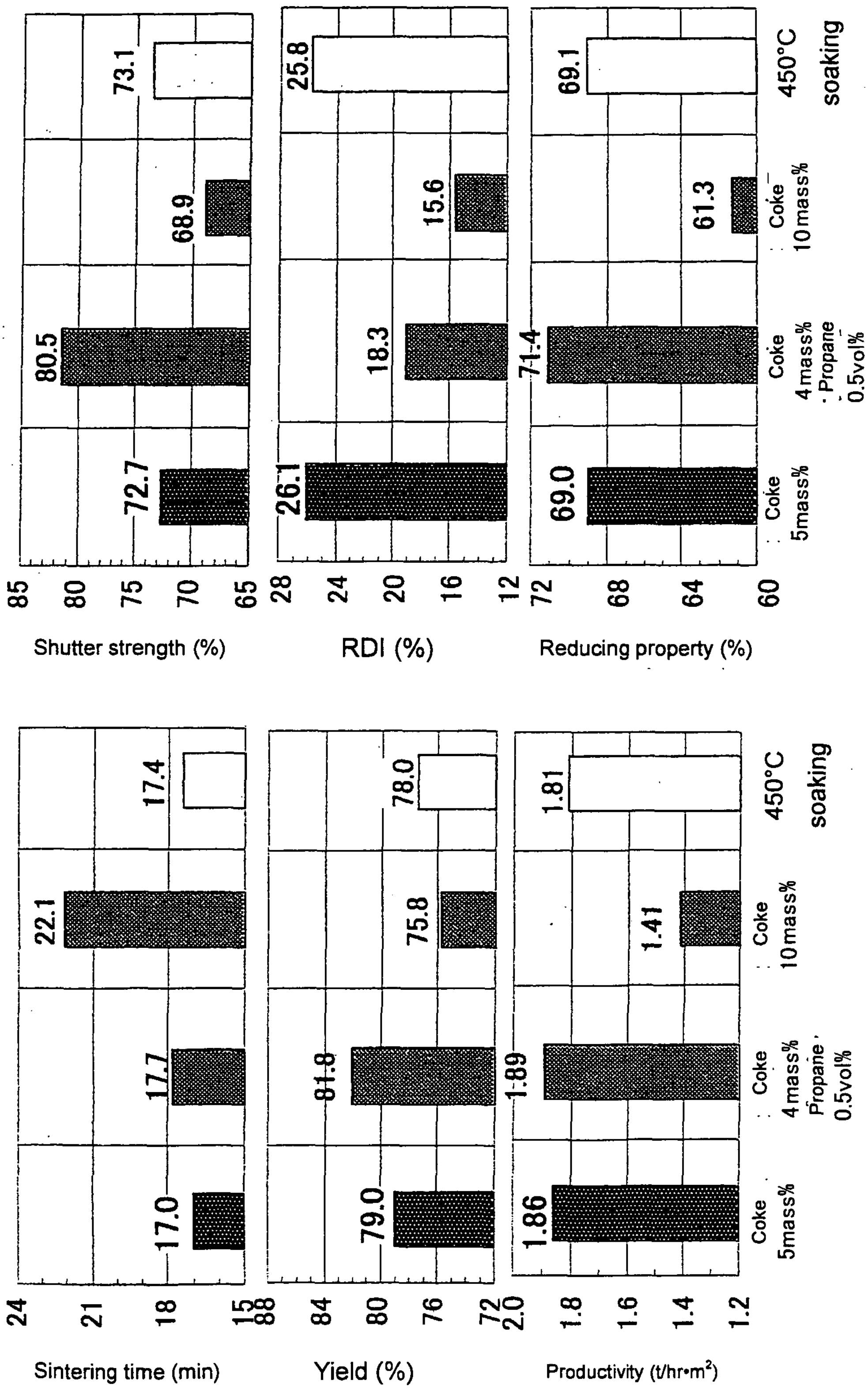

Shutter strength (%)
85
80
75
70
65
72.7
80.5
68.9
73.1
RDI (%)
28
24
20
16
12
26.1
18.3
15.6
25.8
Reducing property (%)
72
68
64
60
69.0
71.4
61.3
69.1
Coke 5mass%
Coke 4mass% · Propane 0.5vol%
Coke 10mass%
450°C soaking
Sintering time (min)
24
21
18
15
17.0
17.7
22.1
17.4
Yield (%)
88
84
80
76
72
79.0
81.8
75.8
78.0
Productivity (t/hr•m²)
2.0
1.8
1.6
1.4
1.2
1.86
1.89
1.41
1.81
Coke 5mass%
Coke 4mass% Propane 0.5vol%
Coke 10mass%
450°C soaking

FIG. 22

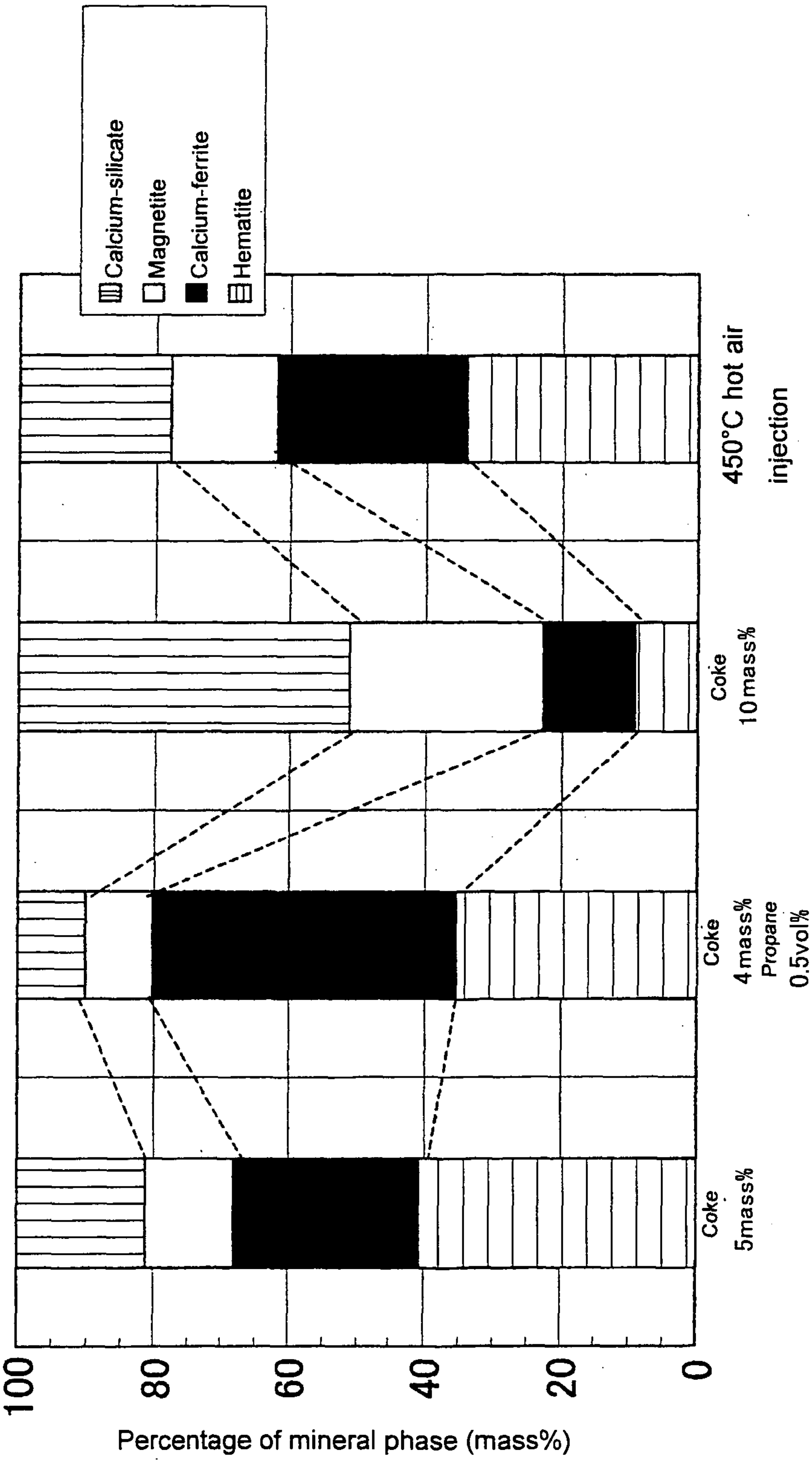

▥ Calcium-silicate
☐ Magnetite
■ Calcium-ferrite
⊟ Hematite
Coke 5mass%
Coke 4mass% Propane 0.5vol%
Coke 10mass%
450°C hot air injection
100
80
60
40
20
0
Percentage of mineral phase (mass%)

FIG. 23

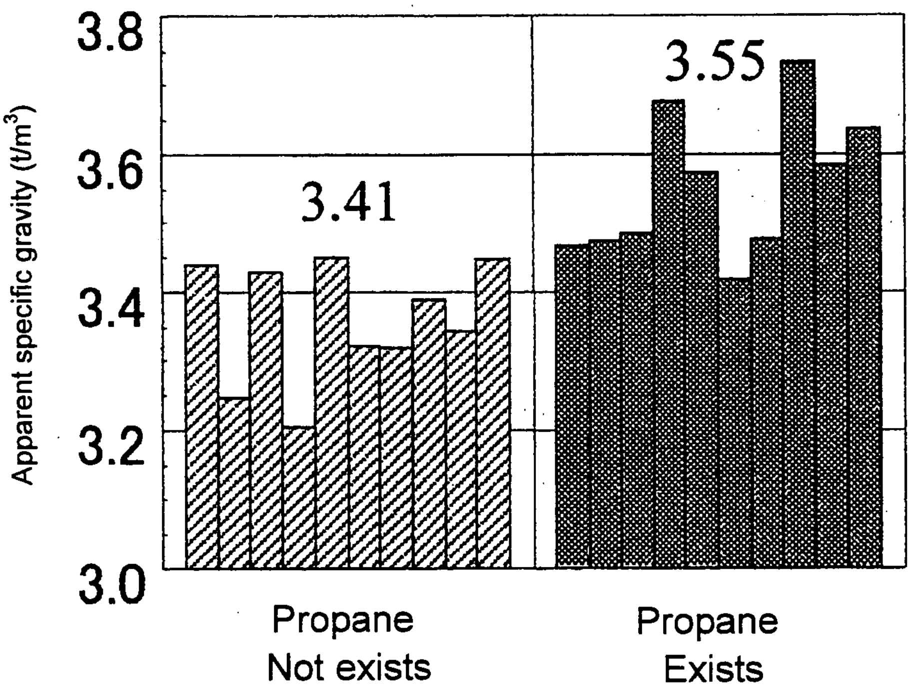

Apparent specific gravity (t/m³)
3.8
3.6
3.4
3.2
3.0
3.41
3.55
Propane
Not exists
Propane
Exists

FIG. 24

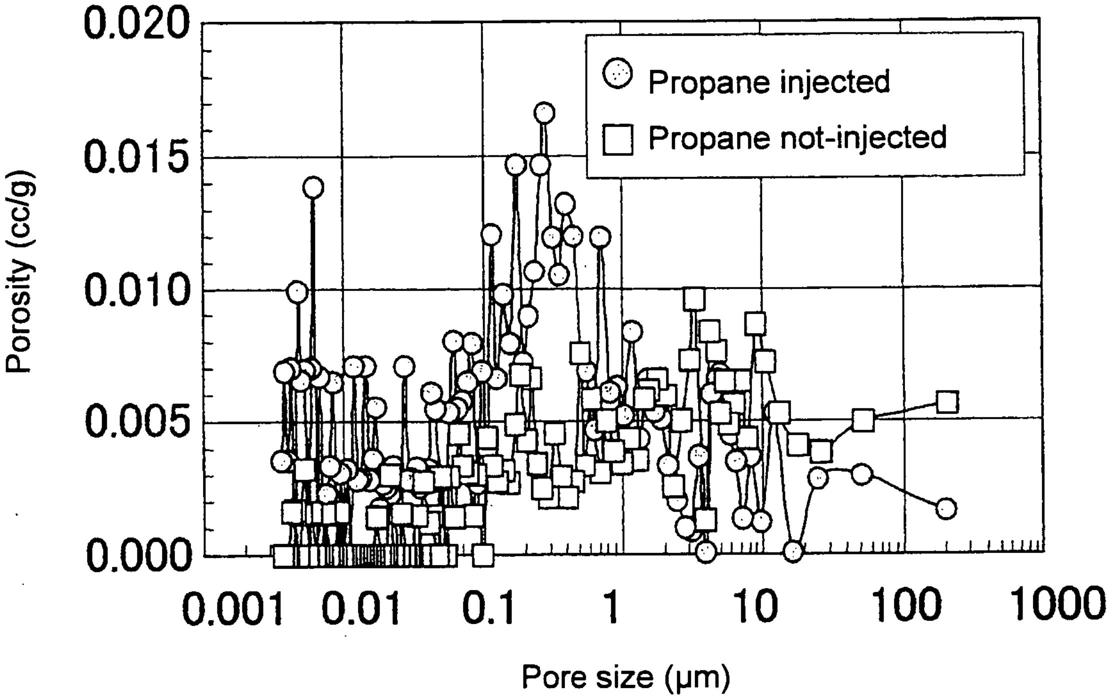

Porosity (cc/g)
0.020
0.015
0.010
0.005
0.000
0.001
0.01
0.1
1
10
100
1000
Pore size (μm)
Propane injected
Propane not-injected

FIG. 25

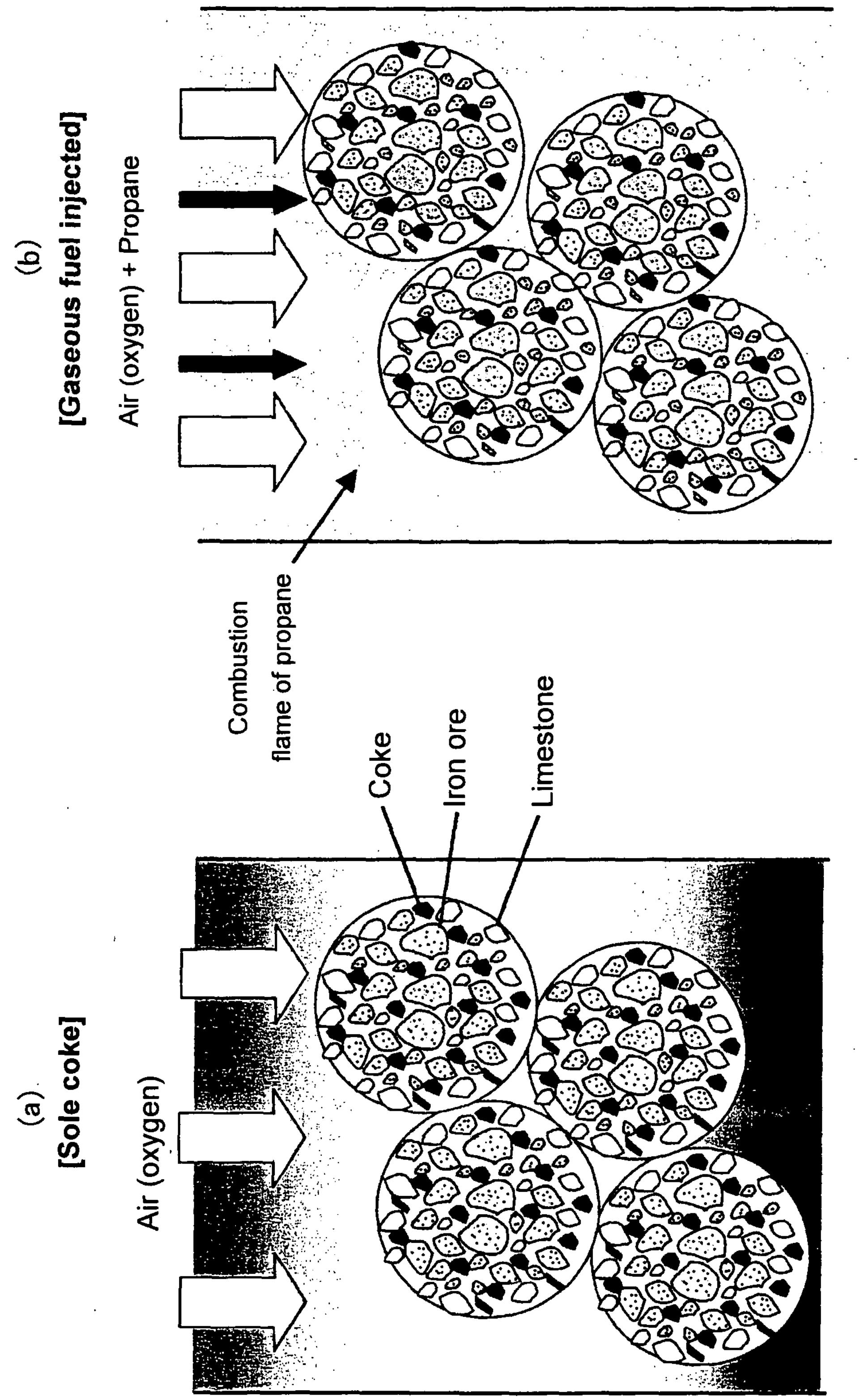

(a)
[Sole coke]
Air (oxygen)
Coke
Iron ore
Limestone
(b)
[Gaseous fuel injected]
Air (oxygen) + Propane
Combustion
flame of propane

FIG. 26

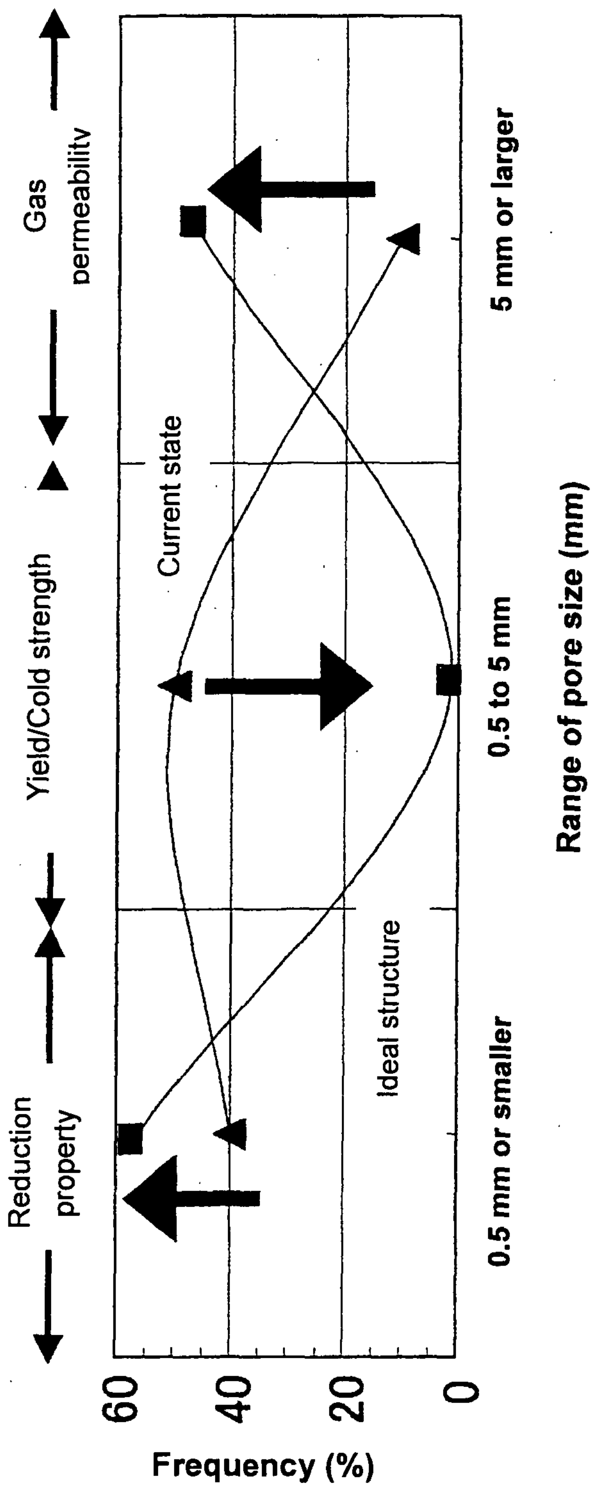

Reduction property
Yield/Cold strength
Gas permeability
Current state
Ideal structure
0.5 mm or smaller
0.5 to 5 mm
5 mm or larger
Range of pore size (mm)
60
40
20
0
Frequency (%)

FIG. 27

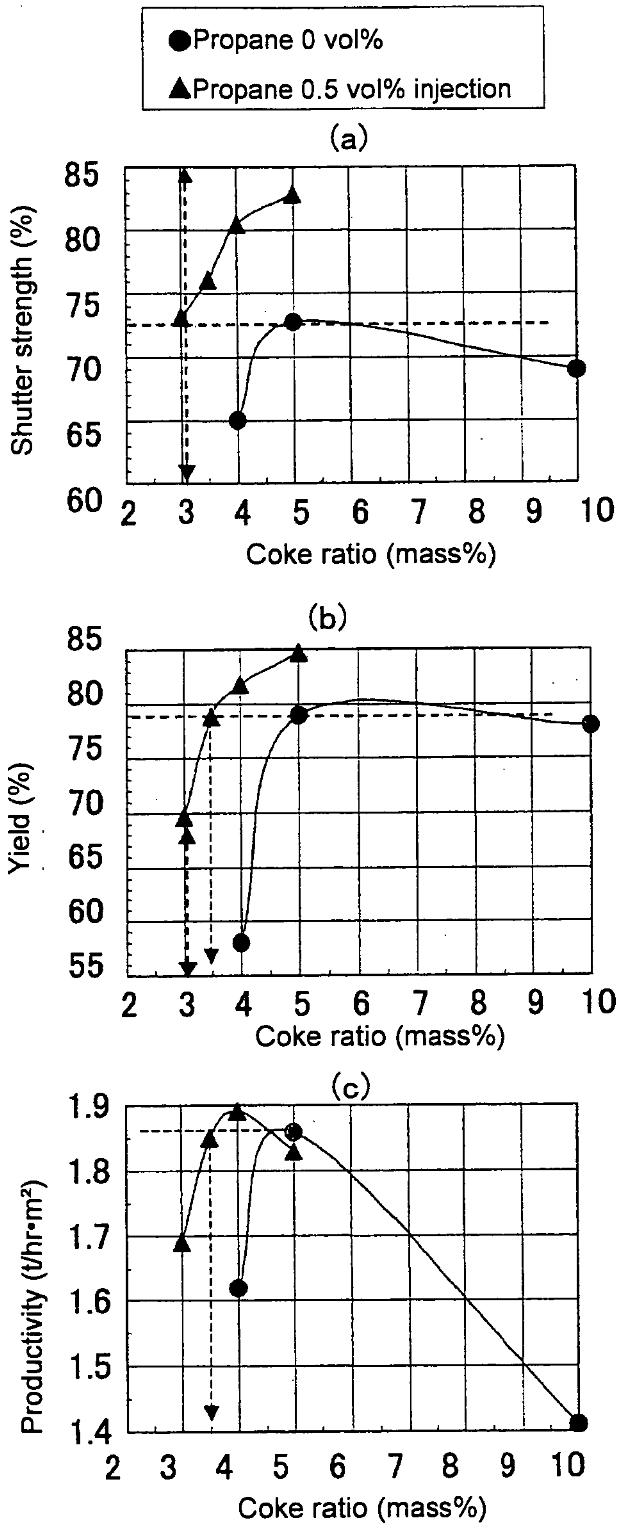
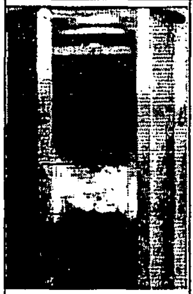
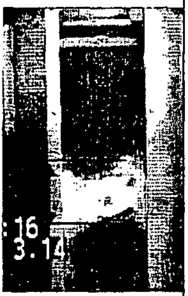
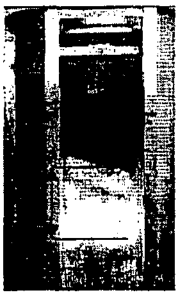

●Propane 0 vol%
▲Propane 0.5 vol% injection
(a)
Shutter strength (%)
85
80
75
70
65
60
2
3
4
5
6
7
8
9
10
Coke ratio (mass%)
(b)
Yield (%)
85
80
75
70
65
60
55
2
3
4
5
6
7
8
9
10
Coke ratio (mass%)
(c)
Productivity (t/hr•m²)
1.9
1.8
1.7
1.6
1.5
1.4
2
3
4
5
6
7
8
9
10
Coke ratio (mass%)

FIG. 28

C gas concentration (to Air)	0vol%	1.0vol%	2.0vol%	2.5vol%
Heat-based propane-converted concentration	0%	0.2%	0.4%	0.5%
Combustion zone				
Width of combustion zone (mm)	50	100	135	150
Sintering time (min)	16.3	17.2	17.0	17.3
Yield (%)	70.7	74.0	74.5	75.6
Productivity (t/hr·m²)	1.58	1.57	1.59	1.63
Shutter strength (%)	69.2	71.6	73.5	75.3

Remarks

1) Coke mixing ratio: 5.0 mass%

2) Charged raw material: Ordinary granulate

3) Bed height: 400 mm

4) Negative pressure: 1200 mmAq

5) C gas injection: Period from 90 seconds after the completion of ignition to the time for the flue gas to reach 70°C.

FIG. 29

Propane concentration (to air)	0 vol%	0.02 vol%	0.05 vol%	0.1 vol%	0.2 vol%	0.5 vol%
Combustion zone						
Width of combustion zone (mm)	75	86	78	96	104	145
Sintering time (min)	15.3	15.1	15.0	14.9	15.2	18.2
Yield (%)	65.5	65.6	64.8	67.0	68.4	68.3
Productivity (t/hr·m²)	1.47	1.48	1.47	1.51	1.54	1.44
Shutter strength (%)	71.8	76.6	76.0	75.8	77.9	82.9

Remarks

1) Coke mixing rate: 5.0 mass%

2) Charged raw material: Coke fine / Limestone covering

3) Layer thickness: 400 mm

4) Negative pressure: 1200 mmAq

5) Propane injection: Period from 60 seconds after the completion of ignition to the time for the flue gas to reach 70°C.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2006/322049

A. CLASSIFICATION OF SUBJECT MATTER
C22B1/20(2006.01)i, *F27B21/08*(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C22B1/20

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2006
Kokai Jitsuyo Shinan Koho	1971-2006	Toroku Jitsuyo Shinan Koho	1994-2006

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 46-27126 B1 (Nippon Steel Corp.), 06 August, 1971 (06.08.71), Claims; page 2, left column, line 8 to right column, line 19; page 3 (Family: none)	1-18,20-27, 29-31
Y		19,28
A	JP 56-51536 A (Sumitomo Metal Industries, Ltd.), 09 May, 1981 (09.05.81), Claims; page 2, lower right column to page 3, upper left column (Family: none)	1-31

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search 01 December, 2006 (01.12.06)	Date of mailing of the international search report 12 December, 2006 (12.12.06)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2006/322049

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 61-48538 A (Kawasaki Steel Corp.), 10 March, 1986 (10.03.86), Claims; page 2, upper right column to lower left column (Family: none)	19,28
Y	JP 64-52029 A (Kawasaki Steel Corp.), 28 February, 1989 (28.02.89), Claims; page 3, lower right column (Family: none)	19,28
A	JP 55-18585 A (Sumitomo Metal Industries, Ltd.), 08 February, 1980 (08.02.80), Claims; page 2, upper right column (Family: none)	1-31
A	JP 48-18102 A (Institut de Recherches de la Siderurgie Francaise), 07 March, 1973 (07.03.73), Claims (Family: none)	1-31

Form PCT/ISA/210 (continuation of second sheet) (April 2005)

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 48018102 A **[0009] [0013]**
- JP 55018585 A **[0010] [0013]**
- JP 5311257 A **[0011] [0014]**
- JP 60155626 A **[0086]**